CONTENTS

PRACTICAL IRON FOUNDING.

CHAPTER I.

PRINCIPLES.

IN this text-book I shall endeavour to explain and illustrate in as clear and concise a manner as possible the principles and practice of iron moulding, a department of industry with which I have been in intimate, almost daily contact since my fourteenth year. Though a rough, dirty trade, there is more of technical skill and forethought required, more of difficulty to be encountered here than in many trades of more apparent importance. And though it is a trade whose practice is very varied and extensive, its literature is singularly scanty. Since a thoroughly exhaustive treatment would occupy a much larger and more costly treatise than this, judicious condensation will be necessary. But if here at the commencement we endeavour to go down at once to first principles, and gain clear ideas as to the fundamentals involved in iron-moulding, we shall be able to obtain such a good and broad grasp of the subject as will assist subsequently in the comprehension of details.

The **matrices** into which iron is poured in order to obtain castings of definite outlines are invariably either of *sand* or *iron*. The process in which the latter is used is a small and comparatively unimportant section, known as *chilling;* the former embraces all the ordinary iron castings—those whose surfaces are not required of a hard and steely character.

Sand is eminently adapted for casting metals into. No material can take its place, because there is none which is at the same time plastic, porous and firm, adhesive and refractory. *Plasticity* is necessary in order that the matrix may be moulded into any form, intricate or otherwise. *Porosity* is essential to permit of the escape from the moulds of the air and of the gases generated by the act of casting, and *firmness* and *adhesiveness* are required to withstand the liquid pressure of the molten metal. A matrix must also be *refractory*, that is, able to resist the disintegrating influence of great heat, and the chemical action of the hot iron itself. It must moreover be cheap, readily available, and not difficult to manipulate. All these qualities are possessed by certain sands, and mixtures of sands, and by no other materials.

The **leading branches of moulding** derive their names from the different kinds of sand mixtures used, termed respectively *green sand, dry sand, loam.* These terms we shall explain directly. It will suffice just now to remark that the fact that sands differ widely in their sensible qualities is apparent to any observant person, so that while one kind will be loose, open, friable, and free,

another will appear as though clayey, greasy, close, and dense. Advantage is taken of these differences in quality to obtain mixtures suitable for every class of moulded work, from the thinnest, lightest rain-water pipes to the most massive and heaviest engine cylinders. Almost invariably, therefore, foundry sand consists of mixtures of various separate kinds. By judicious mixture, grades of any required character can be obtained.

To impart the requisite definite **impressions** and outlines to the sand, it is necessary to employ *patterns*, whose outlines are in the main the counterparts of those of the castings wanted. These patterns are in some cases absolutely like their castings, but in others they only resemble them to a certain extent. Thus, if work is to be hollow, the hollow portions, instead of being provided in the patterns, may be often much better formed in *cores* :—*prints* on the patterns indicating their positions, and the print impressions affording them support. But in much large work, again, the patterns are mere skeletons, profile forms, and the mould is prepared mainly by a process of "sweeping" or "strickling" up.

In order to the **delivery of patterns**, a process of loosening by *rapping* has to be resorted to, and this, together with the *lifting* or withdrawal, tends to damage the mould. To prevent or to minimize this injury, *taper* is given to patterns, that is, their dimensions are slightly diminished in their lower portions, or in those which are last withdrawn from the mould.

As **iron shrinks** during the process of cooling, an allowance has to be given for this "contraction," by making

the pattern and mould larger by a corresponding amount than the casting is required to be. Moreover the forms of some castings are such that they *curve* in cooling, and for this also provision has properly to be made in their patterns.

Iron when molten is a liquid, and behaves similarly to a liquid in all respects; hence the conditions of *liquid pressure* exist in all moulds. The molten iron, therefore, has to be confined at the time of pouring by the resistance of large bodies of sand enclosed in *flasks*, which flasks are loaded or weighted, or otherwise secured. Sufficient area of entry for the metal has to be provided by means of suitable *gates* and *runners*. The shrinkage of metal in mass must receive adequate compensation by *feeder heads*. Owing to the irregular outlines of cast work, flasks must be jointed, and *joints* of various kinds have to be made in the mould itself.

I have made use of several terms in the course of a few lines, and as they are terms which will be perpetually recurring, it will be well before proceeding farther to explain some of those which will not receive more special treatment than they will have here.

CHAPTER II.

SANDS.

THE coal measures, the chalk, green sand, and new red sandstone yield the **moulding sands**; Erith, Belfast, Lanark, Derbyshire, Falkirk, Devizes, Worcester, and many other localities supply them in abundance, and of excellent qualities. The terms "green," "dry," "loam," "floor," "black," "strong," "weak," "core," "facing," "burnt," "parting," "road," etc., have exclusive reference to mixtures, and physical conditions; none whatever to geological character, or to locality.

Sand is "**green**" when the mixture is used in its natural condition, that is, damp, or mixed with just sufficient water to render it coherent. Immediately after the pattern is withdrawn therefrom, the mould is ready, except for the necessary cleaning and mending up, and blackening, to receive the metal. It is also termed "weak" sand to distinguish it from the other mixtures, which by comparison therewith are "strong," *i.e.* possessed of superior binding qualities,—having more "body,"—more coherence.

The "**facing sand**" which is rammed close around, and

in immediate proximity to a pattern is a mixture distinct from that which is used for mere filling of the flasks. There are different "facing" mixtures for green sand, dry sand, and loam. The addition of coal dust is necessary to constitute a facing sand for green and dried moulds. The proportion of dust used is about 1 of dust to 15 of sand for light castings, and of 1 of dust to 6 or 8 of sand for heavy castings. The reason of its employment is, that molten metal slightly fuses the surface of sand with which it comes into contact, and the surface of the casting becomes roughened in consequence. A perfectly refractory sand cannot be employed, there must be a certain percentage of alumina and metallic oxides, which are binding elements, present, to render it coherent and workable, and these happen to be readily fusible. The more silica present in a sand the more refractory it is; thus the well-known Sheffield ganister contains 89 per cent. of silica; but too large a percentage of this in a moulding sand would diminish its necessary cohesive property. The facing sand therefore is introduced into a mould to supply that which is lacking in the main body itself, and by forming a backing of an inch or two in depth to the mould, prevents, by the oxidation of the coal dust, this burning and roughening from taking place. The carbon of the coal yields with the oxygen of the air, at the high temperature of the mould, either carbonic oxide, or carbon di-oxide, and the thin stratum of these gases largely prevents that amount of direct contact of metal with sand which would produce burning and roughening,

from taking place. The reason why a larger proportion of coal dust is required for heavy castings than for light ones, is, that the action of the hot metal is continued longer in the case of the first than in that of the second.

Castings become **sand burnt** when there is not sufficient coal dust used to prevent surface fusion from taking place.

Sand is said to be "**burnt**" and "old" after the carbon of the coal dust has been oxidized at casting. The worst portion of the sand in this condition, or that which clings to the surface of the casting, is thrown away; the remainder is either mixed with certain proportions of new sand, and more coal dust, for facing, or it is allowed to mingle with the "floor sand" to be used only for "box filling." The floor of an old foundry is covered to a depth of from 2 to 3 feet with sand which has been used over and over again for filling the flasks, and making those portions of the moulds which are not in immediate proximity to the pattern. The general term "moulding sand" is therefore applied to that which forms the *floor*, and also, from its colour, "black sand." At the laying down of a new foundry the floor will be made with yellow, red, or other sand, whichever happens to be cheapest. This becomes black by subsequent use, the burning of iron, and admixture of coal dust.

Though ordinary green sand mixtures cannot be **dried** and yet retain coherence, mixtures of close heavy sands are made, which when dried in the stove, are comparatively hard and firm. Only the heavier sands of close

clayey texture will bear drying: green sand mixtures would become friable and pulverize under the action of heat. There is a superficial or "skin drying" practised with these. But that only affects the surface, and is quite distinct from the drying to which our present remarks have reference. Horse dung, cow hair, or straw are mixed with dry sand to render its otherwise close texture sufficiently open for venting: the undigested hay in the dung becoming partially carbonized during the drying of the mould, while the moisture also evaporates at the same time. Coal dust is added to dry sand mixtures as to green sand. Dry sand is mixed and rammed like green sand. Dry sand is said to be "strong" to distinguish it from "weak" or green sand.

"**Core sand**" is in most cases simply a dry sand mixture. It is strictly so for heavy cores. For light cores it is a weaker mixture, approximating more nearly to the condition of green sands.

Loam has a certain affinity to dry sand mixtures in its essential nature; being composed of strong sands and dung. No coal dust, however, is mixed with it, and instead of being rammed like the others, it is wrought wet similarly to mortar, being either struck or swept up with boards, or daubed around patterns or sections of patterns. Dry sand, and loam are mostly used for heavy work, and for work requiring first-class excellence and absolute soundness. Old used loam ground up is one of the main constituents in mixtures of dried sand.

Parting sand is a loose, friable, open, burnt sand, always used without moisture, its purpose being, as its name

implies, to prevent the partial amalgamation or sticking of joint surfaces which are being rammed one against the other. Burnt sand scraped from the surfaces of castings, or new red sand baked in the stove to reduce it to a non-adhesive powder, are used for parting moulds.

It may be noticed that I have refrained from giving definite proportions of sands for different mixtures. The reason is that the proportions of such mixtures must depend entirely upon locality as well as upon the class of work for which they are intended. The red sand or the yellow sand of one locality will not be precisely like that of another locality, and therefore the practice will differ in different parts of the country. Moreover, the mixture of sands, like that of metals, is largely a matter of individual opinion and experience; each foundry foreman follows the practice which in his experience has produced the best results. And again, green sand, dry sand, and loam mixtures are each prepared in various grades to suit different classes of work, differences of strength or body being required, not only in distinct moulds, but even in individual portions of the same mould. But, as generally indicative only of the methods and proportions of mixing adopted, I give in the Appendix a few receipts, some of which I have noted down from time to time, and others for which I am indebted to various firms in the country.

For the **mixing of sands**, various pieces of apparatus are employed. The most complete pulverization and intermixture are necessary, and this is variously done. The sand of the floor, used for mere box filling, is simply

damped with water from a water-can or bucket, and turned over and over with the shovel; any lumps being also broken with the shovel, and then passed through a riddle of $\frac{1}{4}''$ or $\frac{3}{8}''$ mesh. For facing sand mixtures, the various proportions required are first coarsely riddled or sifted separately, and again sifted after admixture. When dried loam is used, or when the sand is very lumpy, it is usually broken up with a flat rammer. The mixture is then turned over with the shovel and riddled for the purpose of intermixture and of uniformity. In small shops, hand-riddles are employed, being slid to and fro over a light horse formed of wrought iron bars. But the most economical method is to use a special sand sifter, which besides being of a larger capacity than a riddle, has the rocking to and fro motion imparted automatically.

These **sand sifters** are made in two forms, to be worked either by hand or by power. Fig. 1 shows a power machine. Its construction is very simple. The tray is formed of a piece of $\frac{5}{16}$ plate bent round to form three sides of a rectangle; the fourth side, that to the right, being open. A series of $\frac{1}{2}''$ bars pass across the frame, the action of the uppermost bars being to assist in the breaking of the larger lumps of sand. Over the lower bars is laid the sieve, whose mesh may vary from $\frac{1}{8}''$ to 1 in., the sieves being loose and interchangeable. Stay-rods screwed at the ends pass from side to side. Slings depend from any convenient support, and are hooked into straps bolted upon the outsides of the frame. The oscillating motion is imparted to the frame from the belt pulley seen to the left, driving the three-toothed cam

pinion. These teeth thrusting alternately the pins in the slotted piece attached to the bar which actuates the

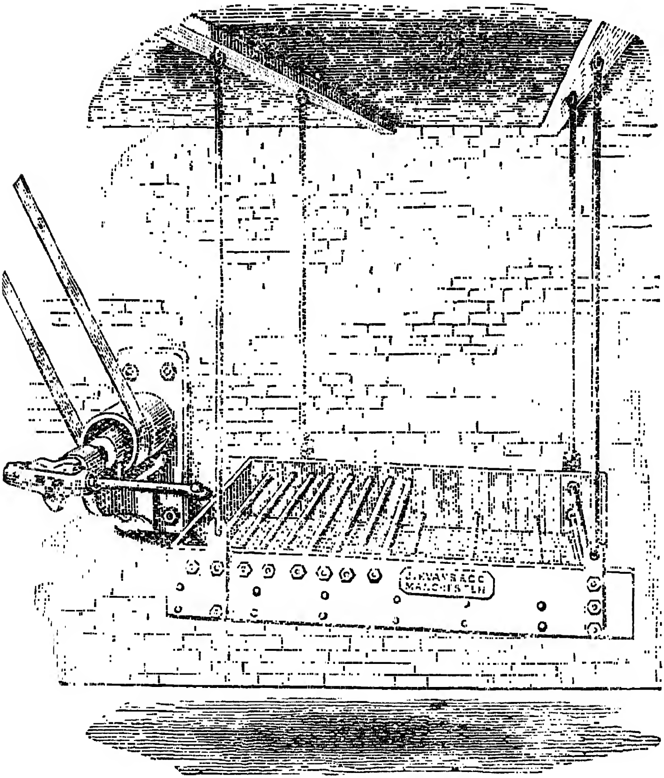


FIG. 1.—SAND SIFTER.

frame, communicate a rapid to and fro motion thereto. The fine sand falls through the sieve into a bin below,

and the unbroken lumps pass on and fall out at the open end, the tray being slightly inclined in that direction, as shown.

The **sizes of mesh** of sieves and riddles range from $\frac{3}{4}''$ downwards. The term *riddle* denotes dimensions down to $\frac{3}{16}$ mesh, *sieve* includes any size less than that, the numbers being given as from "6 to 18" mesh. A foundry riddle is shown in Fig. 2. All these sizes are required in the different sections of moulders' work.

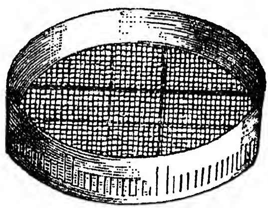


FIG. 2.—RIDDLE.

For **mixing loam** a different method has to be adopted. All the ingredients have to be *ground up* together with water. A mortar mill, termed, from its special function, a *loam mill* (Fig. 3), is then employed. This must be driven by power, and the whole structure requires to be massive. The belt-pulley at the left drives a bevel pinion which actuates a bevel wheel underneath the pan. This in turn operates on the heavy grinding rollers, its shaft passing through the bottom of the pan. After the loam is ground, the pan is emptied by opening the door in the side, seen at the front of the figure.

For **grinding coal** for facing sands, and blackening, a

mill of another type is used; this is sometimes a revolving cylinder, rotating with its longitudinal axis in the horizontal position, having loose heavy rollers inside, which, as the cylinder revolves, remain in the bottom by

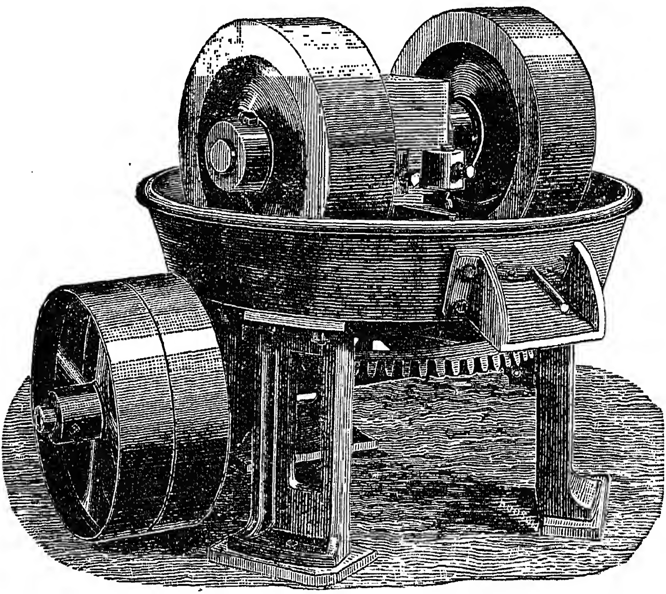


FIG. 3.—LOAM MILL.

reason of their weight, and crush the coal or coke, introduced before the mill is started through a door at the top of the cylinder. An improved form is shown in Fig. 4. Within the pan there are heavy balls set revolving by the vertical spindle passing through the

cover. The spindle is driven through bevel wheels by the belt-pulley to the right. There is a cover of wood for the introduction of the coal, and to prevent the

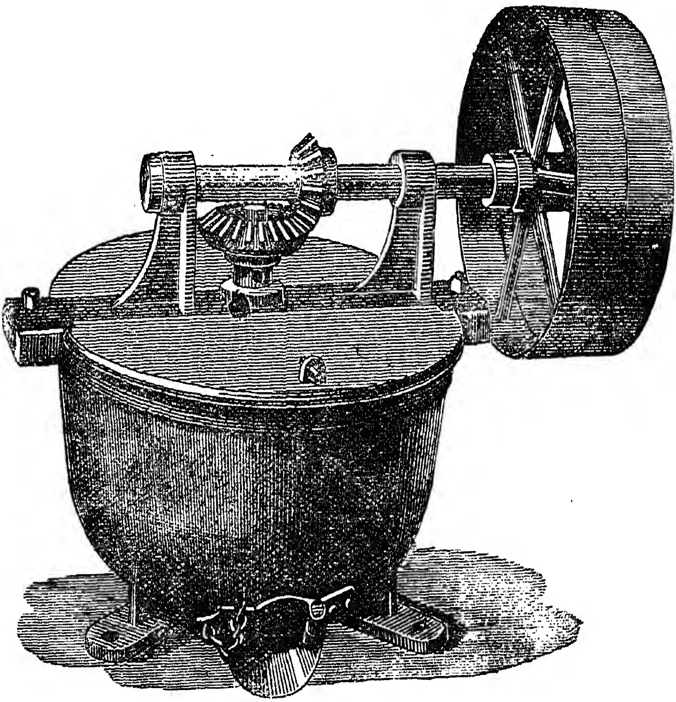


FIG. 4.—COAL MILL.

flying out of the dust. The ground coal is taken away through the door in the bottom of the pan.

CHAPTER III.

SHRINKAGE—CURVING—FLASKS—TOOLS.

BEFORE entering into the numerous details of moulding, which will receive due treatment in the body of this work, I want to explain here some of those primary matters which relate to the preparation of all moulds alike.

Though the laws which govern **shrinkage and curving** of castings are somewhat obscure and uncertain, yet little difficulty is experienced in making allowances sufficiently exact for all practical purposes. Curving, however, as a rule gives greater trouble than shrinkage.

The **linear shrinkage** of all ordinary iron castings is pretty constantly $\frac{1}{8}''$ in 15 in. If, however, a casting is exceptionally light a rather greater allowance should be made, say $\frac{1}{8}''$ in 12 in., if unusually massive a smaller allowance, say $\frac{1}{8}''$ in 18 in. or 20 in., and in the case of a very massive solid casting the shrinkage appears to be almost *nil.* A casting will apparently shrink less in the direction of its depth than in that of its length or breadth, but this is apparent rather than real, for a very deep casting will be found on careful measurement

to have shrunk to the normal extent, showing that the apparent diminution in the vertical shrinkage of shallow castings is due to secondary causes, chief of which is the springing or straining upwards of the cope by reason of liquid pressure. Castings whose central portions are hollowed with numerous dried sand cores, and which are rendered rigid by ribs, or which are plated over, do not, as a rule, contract so much as those in which shrinkage is unimpeded, as for example in those cases where the centre is cored with green sand, or when metal is not massed heavily about the centre. Thus, a cog wheel with arms will shrink less than a mere ring of teeth. Hard white iron also shrinks much more than the soft grey kind—roughly, twice as much—and strong mottled iron occupies a position about midway between the other two. When, therefore, it is stated that the shrinkage of iron equals $\frac{1}{8}''$ in 15 in., that is given as a good average, which I have for my part confirmed by an extended series of measurements; $\frac{1}{8}''$ in 12 in., as sometimes stated, is not correct for ordinary work, but only so for the lightest castings, for which it is about a proper average.

Of the **curving** of castings I can give but the barest summary here. An excess of metal in the form of a rib on one ride of a *long* casting invariably induces a hollow curvature on that side, the curvature increasing with the amount of disproportion. Where there are two flanges of unequal thickness in a *long* girder or girder-like casting, concavity will result on the side of the *heavy* or *thick* flange. When, in a column or pipe

the metal is of unequal thickness, the casting will "go" concave on the side where the metal is thinnest,—the direction of curvature being precisely the reverse of that which is witnessed in a girder or in a ribbed casting. Both sets of facts are, however, consistent with one another, though I can do little more than state them here, not having space to discuss these interesting matters *in extenso*. In brief, the explanation appears to me to be[1]:—that in the column the disproportion in thickness is so slight, that cooling, and the initial shrinkage, and consequent curving of the thin side remains permanent, while in the case of the girder, though the thin flange shrinks and curves first, yet sufficient heat is transmitted from the heavy flange through the web to maintain the thin flange in a semi-plastic condition. Cooling slowly therefore under restraint, its crystals remain somewhat large and its texture open, and its total shrinkage is thereby diminished. Finally, the heavy flange shrinks to its full extent, more so than the thin one, whose shrinkage has been delayed and diminished. The heavy flange consequently becomes concave, pulling the thin flange, still at about its own temperature, convex. Figs. 5, 6, 7, 8, show typical sections, which, if *long relatively* to their cross sections, will infallibly become concave in cooling on the sides marked *A*. In the shops this curvature is termed *camber*, and a pattern is "cambered" to the precise amount by which its casting is expected to curve, and in

[1] See "Industries," vol. iv. p. 417.

the opposite direction. It is, however, only possible to design patterns to neutralize the curvature in unsymmetrical castings by much observation of actual cases, experience, and very often in new work, some tentative measures being the only guides; all depends on *relative* proportions, that is on *length*, as well as on cross section, a vital point which must be ever borne in mind.

Flasks or **moulding boxes** are employed for enclosing either in part or entirely all moulds excepting those which are made in open sand. The lower portion of a

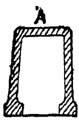


FIG. 5.

FIG. 6.

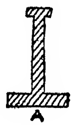


FIG. 7.

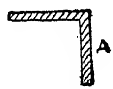


FIG. 8.

SECTIONS LIABLE TO CURVE.

mould may be in the sand of the floor, and its upper portion in a flask. Or the entire mould may be contained in flasks above the level of the floor sand.

The upper portion of a covered in mould is termed the *cope*, and the flask corresponding therewith is also termed the cope, or often the "top part." The flask in the bottom, or that which lies on the floor, is called "the *drag*," or "*bottom part*." If there is a central flask, that is named the "*middle*" or "*middle part*." These are shown in the group, Fig. 9. In this group, *A* is a cope, *B* a drag, and *C* a middle part.

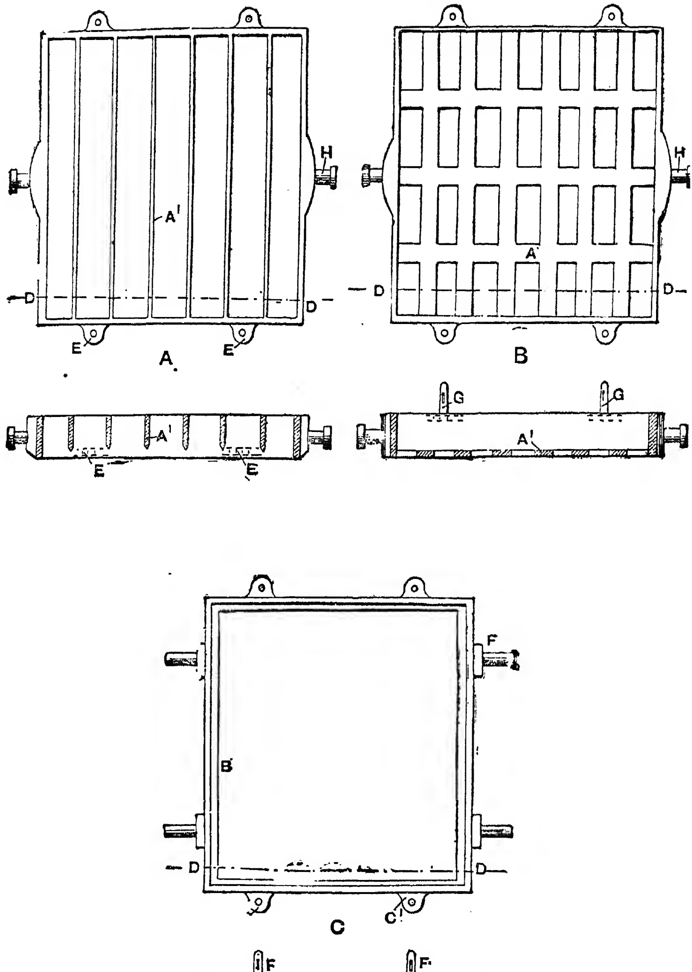


FIG. 9.—FLASKS.

It follows from a consideration of the obvious functions of flasks that they must fulfil these main conditions—they must be rigid and strong, able to retain their enclosed sand without risk of a "drop out" occurring, and their joints and fittings must be coincident, so that after the withdrawal of the pattern they shall be returned to the precise position for casting which they occupied during ramming up.

Rigidity and strength are obtained by making the flasks of cast iron of sufficient thickness. Occasionally they are made in wood, this being a common practice in the United States, but the general practice here, and by far the best, is to use cast iron. The evils of a weak and flimsy flask are, springing during the process of turning over and of lifting, causing fracture of the sand to take place, and portions to fall out; and springing or straining of the cope at the time of casting, producing a thickening of the metal over the strained area. A flask should not be excessively heavy, but at least it requires to be strong and rigid.

Various devices are adopted in order to ensure the retention of the contents of flasks. Chief among these are the **bars or stays** by which they are bridged, A^1 A^1 in Fig. 9. These are ribs of metal usually cast with the frames, though sometimes bolted therein, to be detachable therefrom. They are arranged for the most part at equi-distant intervals. Their forms differ. Thus the typical bars for drag flasks are flat, Fig. 9, B, A^1, their function being the retention of the sand which lies thereon, and which but for the bars would mingle with the sand

on the floor. Only in the case of special flasks, as for example those used for pipes, columns, and for repetition work (Figs. 10 and 11) in which the bars follow the contour of the pattern, is this practice departed from The bars in the cope (Fig. 9, *A*, *A*[1]) are made on an essentially different plan. Here they are never flat, but always vertical, being rather of the nature of ribs than of bars. For general work they are parallel, as in Fig. 9, but for special work their lower edges are cut to the contour of the pattern which they cover (Figs. 10 and 11). These edges are kept to a distance of $\frac{1}{2}''$ or $\frac{3}{4}''$ away from the patterns. They are always chamfered also, Fig. 9, *A*, because if left flat, the sand lying immediately underneath the bars would be insufficiently rammed. Being chamfered almost to a knife-edge, the full pressure of the rammer is exerted immediately underneath the bars, as elsewhere.

There are no stays in middle parts excepting for some special work. Middles for general work are always left clear of bars, as in Fig. 9, *C*, because they have usually to contain a zone of sand only, the central portions being open. To retain this zone of sand, **rods** and **lifters** are employed, whose function and mode of use are described at p. 41. Lifters are also employed in the cope. A rib is cast around the inner bottom edge of a middle, Fig. 9, *C*, *B*, to assist in the retention of the sand, and also as a convenient support for the rods which help to carry the lifters and the sand.

Flasks are always cast with a very rough skin, the better to retain their contents. They are made in open

moulds, no blackening is used, and their faces are often purposely hatched up to increase their adhesive power.

The coincidence of the **joints of moulds** is effected differently in the case of work which is bedded in, than in that which is turned over. Thus, the mould being *bedded* mainly in the floor, the cope is set by means of *stakes* of wood or iron; but being *turned over*, the flasks are fitted with *pins.*

In the first method, one example of which is shown at pp. 62, 64, the pattern having been bedded in and rammed up as far as the joint face, parting sand is strewn thereon, and the cope lowered into its position for ramming. Before being rammed, however, its permanent place is definitely fixed by the stakes, which are driven deeply down into the sand of the floor alongside of the lugs, Fig. 9, *A*, *E*, *E*, or other projections standing from its sides. See also p. 71, Fig. 45 *D*. Being then rammed, and afterwards lifted off for withdrawal of the pattern, and cleaning and finishing of the mould, it is returned and guided to its original position by the stakes in the floor.

In the second method the lugs cast upon the sides of the flask parts have holes drilled or cast to correspond with each other, and long turned pins are bolted into the lugs which are lowermost, and pass into the corresponding holes in the lugs above. The more care which is taken with the fitting up of these lugs the more accurately will the boxes and consequently the mould joints correspond. The length of the pins should be settled with reference to the nature of the work. In any case the pins should enter their holes before any portions of

the opposite mould faces come into contact. Unless the pins guide the closing mould there is always danger of a crush of the sand occurring. In shallow flat work, therefore, the pins may measure no more than 3 in. or 4 in. in length. But in work having deep vertical or diagonal joints the pins may require to be 8 in. or even 10 in. long. The practice is usually to make the pins point upwards. Thus, in Fig. 9, the parts of the flasks are represented in their correct relations for super-position at the time of final closing of the mould. *B*, the drag, has its pins *G*, *G*, pointing upwards ready to enter into the lugs C^1, C^1, of the middle *C*. The pins *F*, *F*, of *C* also point upwards to enter into the lugs *E*, *E*, of the cope *A*.

The best method of securing the pins is with cottars (Fig. 12); sometimes, however, in deep moulds cast vertically, the pins are short, and the ends are tapped and the tightening is effected with nuts.

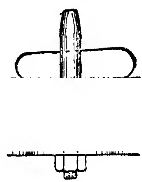


FIG. 12.—PIN AND COTTAR.

When flasks are retained in position with stakes, cottaring or screwing cannot of course be effected, yet great counter pressure is necessary to prevent a cope from being strained and lifted at the time of pouring. *Weights* are therefore employed for this purpose, the amount required being estimated roughly according to the area of the mould, and its depth from the pouring basin.

If the contact area of a cope measured four feet square, and the height of pouring basin were one foot above it,

the amount of weight required by calculation to keep it down, including its own weight, would be $48'' \times 48'' \times 12'' \times \cdot 263$ lbs., the latter being the weight of a cubic inch of iron. This would give us 7,121 lbs. required for loading, or over $3\frac{1}{4}$ tons. Actually, a moulder seldom attempts to calculate the weight necessary to load a flask properly, because so many other conditions have to be considered besides the simple laws of hydrostatics. There is a good deal of pressure due to momentum to be taken into account. Metal poured directly into the mould will exercise more straining action than that led in at the side. Rapid pouring again will cause more momentum than slow pouring. Hot metal will induce more strain than dead metal. Risers relieve strain. The moulder, therefore, loads according to the best of his experience and judgment, and not by calculation, which alone would often lead him astray.

There are numerous **minor attachments to flasks**, used both for general and for special purposes. All flasks require to be turned over, either for ramming, or for cleaning up of the mould. For this purpose handles are provided in the small flasks, and middles, Fig. 9, *F*, and swivels in larger ones, Fig. 9, *H*, and Figs. 10 and 11. The swivels rest in slings depending from a cross beam, the beam being suspended from the crane the while. Since handles and swivels require to be very firmly secured in place, they are not only made of wrought iron and cast in position, but the metal is increased around that portion which is cast in, as shown in the figures 9, 10, 11.

There are other attachments, as handles (Fig. 11, *B*, *B*) for turning over flasks which are too long to be slung in the crane in the manner just noted, and for lowering them into the foundry pit for vertical casts. There are also flanges, *C*, *C*, in the same figure, for the attachment of "back plates," that is, plates of cast iron bolted to the backs of deep flasks which have to be poured vertically, and which are subject, as all deep moulds are, to enormous liquid pressure. The back plates prevent all risk of the pressure forcing out the molten metal, and so producing a waster casting.

The forms of flasks vary widely, being rectangular, both square and oblong, and having ordinary, or special bars. Or, cope and drag may be precisely alike, and bars be alike in each, as in Figs. 10 and 11, which represent pipe and column boxes, Fig. 10 being for pipes, and Fig. 11 for columns. The sides are bevelled in Fig. 10 to economize the time spent in ramming, a consideration when large numbers of casts are required. In Fig. 10 and Fig. 11 the holes *D* in the ends are for the purpose of allowing the ends of the core bars to project through, see Chapter VII. Flasks are also circular for circular work, or of irregular and unsymmetrical outlines to suit work of special character. In jobbing shops, flasks will be sometimes fitted with interchangeable bars bolted in place. Pockets also are often fitted at the ends, which are then bolted on, to be removable, the object being to increase the length of the flask. Sometimes pockets are bolted on the sides to take branches, and holes are cut through the flask sides next the pockets. In all these

cases the question to be decided is one of relative cost, as between the expense of the alterations, and that of a new flask. Flasks cost little for making, and the metal is always worth nearly its first value for re-melting. The dimensions of flasks will range from 6 in. to 12′ 0″ square, or from 1′ 6″ to 20′ 0″ long, if of oblong form.

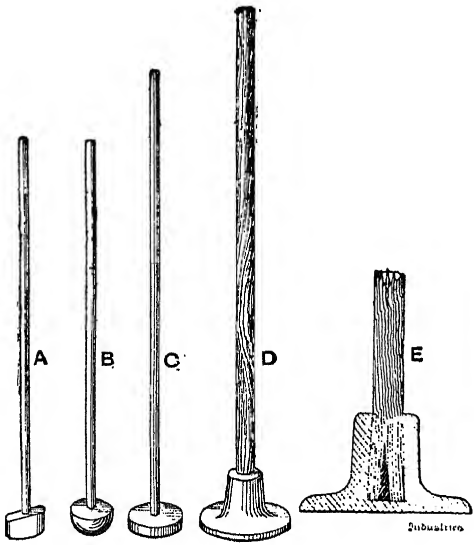


FIG. 13.—RAMMERS.

The general appliances used in moulding, omitting those of the nature of machines, and those not directly employed in moulding, are shovels, lamps, riddles, sieves, buckets, water-cans, bellows, oil-cans. Shovels are used for sand-mixing and box-filling, lamps for

giving light into the darker recesses of moulds; the uses of riddles and sieves have been described, p. 12; buckets and water-cans are used for damping sand and swabbing moulds, bellows for blowing away parting sand and loose particles generally, oil-cans for pouring oil over chaplets, and on damped corners and sections of moulds to prevent the metal from bubbling and causing scabs. These tools are all provided by the employer for general use.

The **small tools** used by moulders, and mostly provided by themselves, though not numerous, are very characteristic of the work done. Foremost among them is the "rammer," varieties of which are shown in Fig. 13, *A* being the usual form of "pegging rammer," *B* another form, *C* and *D* "flat rammers." *A* and *B* are employed for consolidating the sand in narrow spaces, and generally for all the earlier stages of ramming, *C* and *D* being used only for final flat ramming, or finishing over of surfaces. *E* shows the manner in which the flat rammer is handled, a wedge at the lower end being driven home by the forcing down of the handle into the socket of the rammer head.

"Vent wires" are shown at Fig. 14, *B* being a small "pricker" or "piercer," as it is sometimes called, the other, *A*, being larger and requiring considerable force to use. The smaller wire, which may be from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. in diameter is employed for piercing the sand in the immediate vicinity of the pattern with innumerable holes, all leading into larger vents, or into the "gutters" in the joint faces. The larger wires will range from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. and are used for venting down to cinder beds

underneath flasks, and around the edges of deep patterns, bringing off the vents from the smaller channels.

The "trowels" (Fig. 15) are in perpetual request for smoothing or sleeking the surfaces of moulds, for spread-

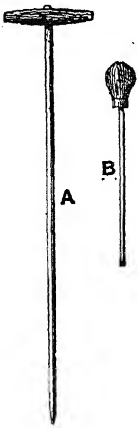


FIG. 14.—VENT WIRES.

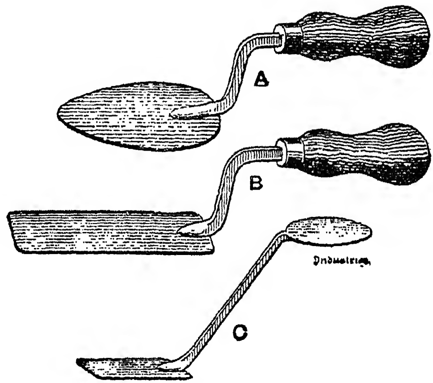


FIG. 15.—TROWELS.

ing and smoothing the blackening, and for mending up broken sections of moulds. They are also employed for "finning" joints of dry sand moulds, for marking lines on sand faces, and are improvised for many purposes

FIG. 16.—CLEANER.

beyond those for which they are legitimately designed. *A* is the common "heart" shape, *B* the "square" trowel, and *C* the combination, or "heart and square" form.

Fig. 16 is a "cleaner," a tool used for mending up and

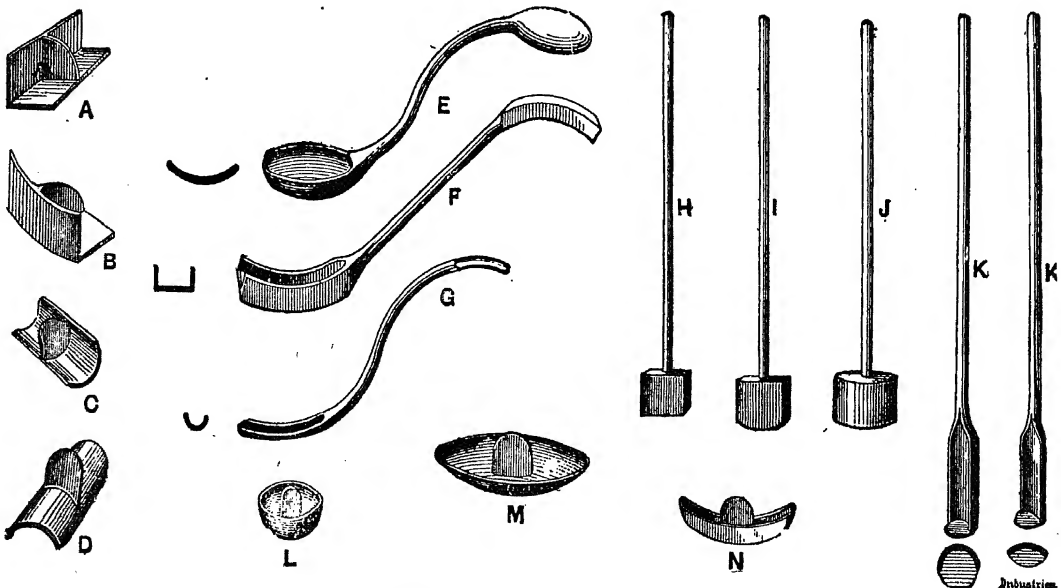


FIG. 17.—FINISHING TOOLS.

smoothing the deeper portions of moulds which cannot be reached by the trowel.

The remaining figures (17) illustrate finishing tools. *A* is a "square corner sleeker," also spelt "slicker," or "slaker." *B* is a similar tool except that one face is adapted for sweeps, hence called "flange corner sleeker." *C* is a "bead tool or smoother," or "pipe smoother," for smoothing the impressions of beads or sweeps of that section. *D* is a "hollow bead." *E* is a "spoon tool." *G* is a "bead tool" curved lengthwise. *F* is a square or "flange" bead. *H*, *I*, *J*, are "flange tools," *K*, *K*, "boss tools." *L* is a "Button sleeker" or "bacca box smoother," *M* an "oval pipe sleeker," *N* another pipe sleeker. These tools, with a rule and calipers, complete the private kit of a moulder.

CHAPTER IV.

GREEN SAND MOULDING. PART I.

THIS branch embraces by much the largest proportion of cast work done, being not only cheap, but sufficiently good for all except some few special purposes. The meaning of the term "green sand" was explained on p. 5. The methods of moulding in green sand will be described here.

These methods are broadly classified under three great divisions, namely, moulding in **open sand, bedding in,** and **turning over.** By one or another of these, all work which is made in green sand is accomplished; and, omitting the first, all work in dry sand also.

Moulding in **open sand** signifies that the mould is uncovered on its upper face. In the *closed* moulds, the metal when poured is arrested at a certain definite stage by the face of the sand in the cope. The face of that sand may have any contour, irregular or otherwise, but the upper face of a casting made in open sand can only be truly horizontal, which fact alone at once limits the utility of open moulds. But beyond this, the upper surface of a casting made thus is always

irregular, rough, porous, unsound:—irregular and rough, because the hot bubbling iron is not confined against a face of sand, but begins to set ere the commotion due to the evolution of its heat, and of the gases and air, has subsided,—porous and unsound, chiefly for this reason, and partly because it is not cast under pressure, as are all closed moulds; the pressure in these being due to the height of pouring-basin above the surface of the mould. Castings made in open sand are therefore only employed for rough work, never for ordinary engineering constructions. Moulding flasks, back plates, foundation plates, core plates, rough weights used only for loading, and similar articles are made in open sand.

The main essential in this class of work is to have the mould perfectly level, a matter comparatively unimportant in closed moulds. Hence in such work, either a level bed of sand is first prepared, and the pattern or skeleton of the pattern, or sectional portion of the pattern, as the case may be, is laid upon this and rammed. Or the pattern is bedded in and levelled during the process of ramming. Venting is seldom done except when the sand happens to be of very close texture, but the air comes away partly from the upper face of the casting, partly through the bottom sand.

Usually an open sand mould is made $\frac{3}{8}''$ or $\frac{1}{2}''$ deeper than the casting is required to be, and overflow channels are cut around the edges to carry off the superfluous metal, and to indicate the proper time for the cessation of pouring. A good deal of work in open sand is shaped by the moulder himself with the aid of a few strips and

sweeps only, but then it is the roughest class of moulded work done.

Bedding in signifies the moulding of patterns in the sand of the foundry floor, the position of the mould being in no respect changed from the commencement of operations until the time of casting. In this method it is obvious that the lower faces of the mould—those which are formed underneath the pattern—will not be easily rammed, and may be harder and softer alternately.

Turning over, on the contrary, signifies that the face of the mould which is lowermost at the time of casting, is uppermost at the commencement of ramming, being subsequently turned over. By this last method it is clear that the portion of the mould which is finally lowermost will be rammed as evenly and well as the upper portion, since it has already been in the top at the earlier stage of ramming: and it is evident that the consolidation of the sand over any given area will be more perfect when it has been rammed directly *against* a pattern, than when the pattern has been simply *beaten down* into a bed of sand. But it is also evident that since in turning over, the whole of the mould is contained in flasks, this method requires more "box parts" or flask sections, and increases the *weight* which has to be lifted by men, or with cranes, or travellers; and is therefore more expensive than bedding in. The larger and heavier the work, the greater the reason then why bedding in should be adopted in preference to turning over. In massive work, therefore, the preference is usually given to bedding in, but in moulds of small

and of moderate size, and generally for work of the best class, turning over is the method usually adopted.

When work is **bedded in**, the sand is dug up and loosened to a sufficient depth, and into this the pattern is beaten with heavy wooden mallets, its top face, when practicable, being tested by the spirit level,—usually in conjunction with winding strips. As soon as a very rough impression of the mould is thus obtained, an inch or two of facing-sand is strewn or riddled over the whole area, and the pattern is beaten down again. This hammering down of the pattern causes the sand to become harder in certain sections than in others—becoming hard, it also offers a certain resistance to the further bedding down of the pattern. This consolidated sand is therefore hatched up and loosened, and if need be, portions removed with the trowel, or with the hands, until the pattern is made to bed pretty nearly alike all over. Recesses, pockets, ribs, flanges, and such like, when present, have to be filled in, by *tucking* the sand underneath and around them with the hands, the smaller rammer following afterwards where possible. When the sand is thus rammed and brought up level with the top edge of the pattern, it is scraped and sleeked off, and the joint face made for the cope. This face is then strewn with parting sand, and the cope put on, set with stakes, and rammed.

Though these operations are in general outlines very simple, yet in their practical details they call for the exercise of as much, or perhaps more skill on the part of the moulder than those involved in turning over. The

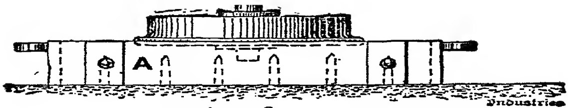


FIG 18.

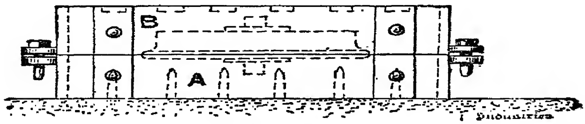


FIG 19.

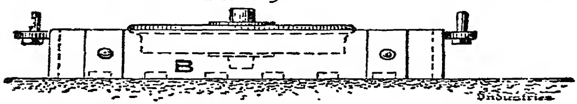


FIG 20.

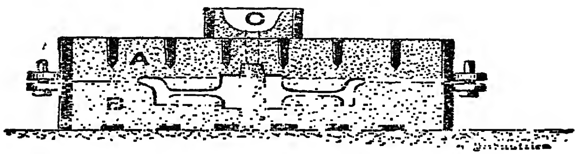


FIG 21.

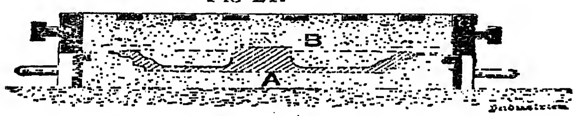


FIG 22.

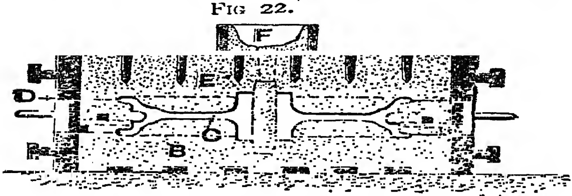


FIG. 23.

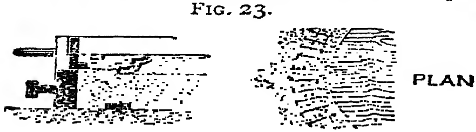


FIG 24.

EXAMPLES OF TURNING OVER.

difficulty in bedding in, lies chiefly in the proper consolidation of the sand. If the sand is of unequal consistence, there will result scabs and blow-holes in the harder portions, and swellings on the castings over the softer portions.

Figs. 18-21 illustrate the moulding of a trolly wheel by turning over. The pattern is first laid with its upper face downwards on a temporary cushion of sand in the flask *A*, Fig. 18, which is presently to form the cope. A joint face is made, which may or may not be in the same plane as the joint edge of the flask, being dependent on circumstances. It is often convenient to slope the sand joint up or down when the relative depths of pattern and flask require it. The joint is strewn with parting sand. Upon this the flask *B*, which is presently to form the drag, is laid, Fig. 19, and rammed permanently. The two flasks then cottared together, are turned over, and the drag *B* is laid in its permanent position upon a bed of levelled sand. The cope is lifted off, its loose cushion of sand knocked out, and the upper joint face of the drag smoothed over, and strewn with parting sand. Fig. 20 represents the mould at this stage. The cope is then placed on, swabbed, liftered, and rammed permanently with runner pin in place. The flasks are then parted at the joint, the mould mended and blackened, cored, closed, and cottared, and the pouring basin *C* made. Fig. 21 represents the mould closed ready for pouring.

The next illustrations, Figs. 22 to 24, are those of a "three parted mould." It is obvious that the groove of the sheave wheel there shown must effectually prevent de-

livery, if moulded in the same manner as the trolly wheel —that is, with a cope and drag only. Two parting joints are necessary to enable the pattern to deliver, and in addition the pattern itself has to be divided through its middle plane. Fig. 22 shows that stage of the mould which corresponds with the stage in the moulding of the trolly wheel seen in Fig. 19. The sand in *A*, Fig. 22, forms a temporary bedding only for the half-pattern over which the drag *B* is rammed for permanence. The flasks *A* and *B*, then cottared together, are turned over, *A* is removed, and the sand knocked out, the exposed joint face of *B* is sleeked, and strewn with parting sand, the middle part rodded and liftered, swabbed with clay-water, and rammed approximately level with the pattern joint, Fig. 24. To sustain the weak narrow tongue or zone of sand which forms the pulley-groove, nails dipped in clay-water are rammed in with the sand as seen in Fig. 24. The upper half-pattern is then put on the lower half and weighted, the sand rammed to the middle plane *D* of its flange, Fig. 23, the joint sleeked over, parting sand strewn thereon, and the cope *E* put on, liftered and rammed. The flasks are then parted, the pattern withdrawn, the mould cleaned, blackened, cored, and closed, pouring basin *F* made, and all is ready for casting, as in Fig. 23.

These, in bare outline, are the general processes of bedding in, and of turning over. I have purposely, in order to avoid confusing the mind of the student, omitted to explain certain important items essential to safe moulding, which we must now consider.

First there is the matter of **venting.** Vents are variously made, according to circumstances. When a pattern is being rammed, the sand by which it is surrounded is pierced with innumerable small *vent-holes* of about $\frac{1}{8}$ in. in diameter, more or less. These do not properly come quite close, but only to within $\frac{1}{8}$ in. or $\frac{1}{4}$ in. of the pattern. When vent-holes come out on the actual mould surface, there is always risk of the metal entering the vents and "choking" them, and, by preventing the escape of air and gas, causing a "waster" casting. All the small vents are brought into larger ones, and the position of the larger ones will quite depend on the nature of the mould. For instance, when a pattern is bedded in, and the area of the mould is large, all the lower surface vents are carried directly downwards into a large porous reservoir of cinders, clinkers, or coke—hence termed a *coke-bed*, or *cinder-bed.* In this, layers of hay alternate with layers of cinders, and the whole is covered with a final stratum of hay. This bed is laid at a depth of 10″ or 12″ beneath the lower face of the mould, and has a total thickness, including cinders and hay, of 10″ or 12″. Into this the vents are carried, and from it the air is led away, and escapes through vent-pipes. Fig. 36, p. 62, illustrates a mould having a cinder-bed and vent-pipes. The larger vent-holes are made with a vent-wire of $\frac{1}{4}$″ or $\frac{3}{8}$″ diameter, usually at an early stage of the bedding in of the pattern, or as soon as the general contour of the mould is obtained, and before the pattern is put back for final ramming up. But after the pattern is withdrawn, the vent openings, if not already closed by the bedding in,

are filled up by the consolidation of the surface sand with the hands of the moulder, which invariably follows upon the withdrawal of a pattern that has been bedded in. By exerting gentle pressure with the fingers over the whole of the surface in detail, the moulder ascertains what sections are not sufficiently firm, and adds fresh sand in those parts, using the rammer for the purpose. At the same time he closes vent-holes which may yet remain open. On first thoughts it may seem strange to make vents and then close their openings, but as a matter of fact, the air and gas will force their way under the liquid pressure existing in the mould, through an inch or thereabouts of intervening sand, to the vents, while the metal itself will be unable to do so.

Diagonal vents are brought from the sides of a mould into shallow channels or "gutters" which are cut in the sand forming the joints of the mould, and are thus carried away at the box joints. The vents from the *upper surface* of a mould are brought off directly through the whole area of the upper surface of the cope sand. In Figs. 21 and 23, the upper surface vents are brought out over the tops of the copes *A* and *E* respectively, covering the whole area. The venting is therefore direct. Vents in the drag, in work which is turned over, are first made directly to the pattern face before turning over, and are then brought out at the joint which the under surface of the drag makes with the levelled bed of sand on which it rests. The necessary connection with the outside of the flasks is made by passing a long vent wire from the outside between those

faces in all directions. The vents therefore in Figs. 21 and 23 pass from the lower faces of the mould perpendicularly through the drags *B* and *B*, and then out at right angles therewith, on a level with the sand floor upon which the drags rest.

The vents from the peripheries of these moulds are brought out diagonally into gutters cut into the mould faces, and the air escapes through the joints of the flasks.

Sand which is rammed hard will require more venting than loosely rammed sand. Free open sand will require less than close loamy sand. The red sands are so free and open that for many kinds of light work no venting is required at all, their natural porosity being sufficient to allow of the escape of the air. In heavy work the vents may be kept farther from the surface than on light work. The more dampness present in a mould the greater the quantity of venting necessary.

Another important matter in moulding is the artificial binding together and retention of large quantities of sand in their flasks. It is clear that the mere ramming of a large mass of sand in a flask, with no other support than that afforded by the sides, and the bars or stays, would not prevent the tumbling out of portions of that sand by concussion, or even by reason of its own weight. Numerous devices are therefore resorted to in order to bind or secure it, both during moulding and at the time of casting. These methods are **rodding, liftering,** and **sprigging,** signifying that rods, lifters, and sprigs are used in different moulds, or in different portions of the same mould, as binding agents.

Rodding means that masses of sand which by reason of their large amount of overhang cannot be supported and stayed by the bars of the flask, are sustained by means of iron rods. Thus, as a typical example, a mass of sand overhanging a flange will be supported by rods whose opposite ends are either sustained by the main body of sand in the mould, or upon a "drawback" plate, or on any ordinary cast iron ring or frame, such as those which are often used for lifting the middle sand in some kinds of bedded-in moulds. Rods are used also in turned over moulds, in the middle flasks, which are always destitute of bars. The general mode of rodding and liftering middle parts is shown in Fig. 35, p. 60, rods of square bar iron being placed across the flask and supported by the ledge (see Fig. 9, *C*, *B*, p. 19) that runs round the inside face. The lifters depend from, and are supported upon these. Similar rods are seen in the middle part in Fig. 23, p. 35.

Lifters are bent rods made both in wrought and in cast iron, the size of cross section and length varying with the dimensions of the work. They may range from $\frac{1}{4}''$ to $\frac{3}{4}''$ in diameter, and from 4" to 24" in length. They rest upon the rods as in Fig. 35, p. 60, or are suspended from the box bars as in Fig. 40, p. 66, and are set and laid in all possible positions wherever sand requires support. In some few cases they are not themselves supported, but simply act as binders within the sand, their bent ends resisting the tendency to dislodgment of the sand in mass. But when practicable they should be suspended from, or be rested upon rigid supports.

Some judgment is required even in the apparently simple matter of the putting in of lifters, since if improperly supported, a tumble out of the sand and lifters *en masse* will probably occur.

Sprigs, that is, common cut nails, are employed for strengthing weak sections of sand which are too small to be sustained by lifters. Or the sprigs may be considered as auxiliary to lifters, strengthening in detail the sand whose principal mass is carried by the lifters. In all work where there are small isolated bodies of sand, narrow weak edges, projections, etc., long nails are inserted in quantity to bind those to the main body. The nails are not only inserted at the time of moulding, but also after the pattern has been withdrawn. Should the mould crack or show signs of giving way, nails are thrust in to strengthen it, and to prevent risk of the sand becoming washed away by the rush of metal. In the economy of mending up, these nails are indispensable. An example of sprigging occurs in Fig. 24, p. 35.

Mending up is necessary in all cases excepting those in which the patterns are made for standard use, regardless of expense, and those in which patterns are moulded by machine. The causes of moulds breaking down are numerous, as, for instance, badly made patterns destitute of taper, of rough construction, having overlapping joints in the wood of which they are composed; the leaving those pieces fast which ought properly to be loose, too soft or too hard ramming, imperfect rodding or nailing, insufficient, or excessive rapping, uneven or jerky lifting. These are the principal causes of the fracturing of moulds.

At the time of withdrawing, or delivery of a pattern, the joint edges of the sand are "swabbed," in other words, they are just damped or moistened with the swab or water brush in order to render the sand around the edges of the pattern as coherent as possible. Then the pattern is *rapped*, that is, a pointed iron bar is inserted in a rapping plate let into the pattern, or otherwise into a hole bored into the pattern itself, and the bar is struck on all sides in succession with a hammer, so loosening the pattern from actual contact with the sand in its immediate proximity. A lifting screw, or else a spike, is then inserted, several screws or spikes being used in work of large dimensions, and the pattern is lifted gently, moderate rapping with wooden mallets on its surface and edges being continued the while.

After the pattern has been removed, the mould is carefully overhauled to note the extent of the damage, if any, which it has sustained. If the lift has been very bad and the work is very intricate, it is better not to attempt mending up at all, but to ram the pattern over again. If the edges chiefly are broken, it is in some cases desirable, as, for instance, in moulds taken from loam patterns, to put the pattern into place again, and make good the sand around the edges, pressing it down with the trowel and increasing its coherence by means of sprigs and the use of the swab. If the damage is of quite a local character, that portion of the pattern corresponding therewith can often be taken off and put back in the mould as a guide by which to mend up.

In sections which are inherently weak, a stronger sand

The causes of scabs are various. As we are speaking now of green sand, we will only mention the causes which produce scabs in green sand moulds. Hard ramming is liable to cause them, and so also is using sand of too close texture, or working it too wet. When ramming a mould, regard must be had to the nature of the casting, and the particular section of the mould which is being rammed. Metal will not lie kindly on a hard bed, but will bubble, the air not getting away with sufficient rapidity, and bubbling will result in the detachment of flakes of sand, and consequent scabbing. If, on the contrary, the sand is rammed too softly, the pressure of the metal will produce lumpy castings. The moulder has therefore to ram the sand sufficiently hard to resist the pressure of metal, yet so soft that bubbling shall not take place. The practical result is a kind of compromise. The lower stratum of sand is rammed hard, and freely vented, and an upper stratum of an inch or two in thickness is rammed more softly. The metal, therefore, lies upon a comparatively soft cushion, which is supported by a firm, well-vented backing. The lower portions of moulds are not as a rule rammed so hard as the sides and top, since the gas can escape more readily from the latter than from the former. A hard-rammed mould will be productive of less risk in the case of a heavy than in that of a light casting. Another cause of scabbing is the leaving of risers and feeder heads open during the actual pouring of metal—a point which we shall mention more in detail presently.

Choking of vents will produce scabbing, hence the

reason why the vent openings are always closed against the face of a mould. Excessive moisture in a mould will produce scabbing by the generation of steam in quantity. The moisture may be due to overmuch watering of the sand in the first place, or to the abuse of the swab at the time of mending up in the second. The amount of moisture in a mould should be just so much as is necessary to effect the consolidation of the sand—anything in excess of that is injurious. Too much sleeking with the trowel also is injurious, and a too thick application of blackening, whether wet or dry, followed by hard sleeking, is a fruitful cause of scabbing, the blackening and the sand beneath flaking off at the time of pouring.

The methods of **pouring** or **running** a mould are very important. Much depends on this apparently simple matter. But in truth there is nothing in moulders' work which is insignificant or unimportant. From first to last care in little, and to a casual observer, trivial things, has to be scrupulously exercised. A trifling neglect may, and often does, ruin the work of several hours or even of days.

Since the conditions of liquid pressure exist in moulds, several things become self-evident. The pouring basin must be higher than the highest part of the mould. The liquid pressure on any given portion of the mould will be statically equivalent to head $\times$ area $\times$ sp. gr. of metal. The pressure on a mould of large area will in any case be very great, and must be resisted by equal and opposite forces. The area of the **ingates** must be sufficient to fill the mould before the metal has time to become chilled or

solidified. Also there are other matters of a purely practical character, which must be illustrated to be properly explained.

Various methods of pouring moulds are shown in Figs. 25-30, pp. 52-54. A mould may be poured direct from the top, or from the bottom, or from both top and bottom simultaneously, or it may be poured from one side. Most moulds are poured from the top direct, Figs. 21, 23, p. 35. When moulds are of considerable depth, or when it is desirable that their surface or skin shall be clean and smooth, that is, not roughened or cut up by the action of the metal, they are run from the bottom or from the sides. For it is evident that metal rising quietly in a mould will not cause such damage to surfaces as metal which, falling from a considerable height, strikes the sides in its descent, and beats heavily on the bottom of the mould. When it is necessary that metal shall be poured from the top into a deep mould, its cutting action is often diminished either by making the mould in dry sand, or by placing a piece of loam cake at the spot where the beating action is most intense, or by inserting a number of flat-headed chaplet nails in close proximity at that spot, and allowing the metal to fall upon them.

As a general rule it may be stated that, unless good reasons exist for the contrary practice, moulds should be poured from the top. Iron falling upon liquid iron remains hotter and in greater agitation than iron rising slowly. The latter will carry up the scum and dirt which it gathers from the sides of a mould, allowing

these foreign matters to lodge under projecting portions; but the metal falling from above cuts up the dirt and scurf, keeping them in such perpetual movement that they can scarcely effect a lodgment in the mould. Running from the bottom, the metal becomes chilled as it rises; but running from the top, the last iron poured is as hot as the first. When running from the top and the bottom at once, the first metal is led in at the bottom, and after a portion of the mould is filled, the top metal is introduced, falling upon metal. The dirt is thus cut up and the iron is kept hot until the mould is filled. No set rules can be laid down for the most suitable method of pouring, the matter is entirely one for the exercise of the moulder's judgment.

Examples of the simplest forms of pouring basins and runners occur at p. 35. These are only adapted for the smallest moulds. For those of moderate and of large dimensions, the forms of the basins and the modes of running are modified. The shape of a typical pouring basin and runner is shown in Figs. 35 and 37, pp. 60 and 64. Though a rough-looking affair, every detail is a matter of design. First there is a depression at *O*. This receives the first inflow of the metal. If there were no such depression the metal on being poured from the ladle would flow at once into the mould, and as some slight adjustment of the ladle is necessary before it is ready for emptying a full stream, a few drops would be running in during the making of such adjustment. These would form "cold shots" in the casting. Also, the iron falling for a considerable time upon a bed of sand would cut it up, and

wash portions into the mould. But the depression in the basin receives and retains the first few droppings of metal, and forms a shallow reservoir into which all the remaining metal falls as into a bath, preventing the cutting up of sand. Only when the depression is filled does the iron begin to flow off in a quiet stream into the mould. As soon as the depression is full the remaining metal is poured very rapidly into the basin until it is nearly level with the brim, and is *kept filled* until the mould is quite full. This is necessary in order to prevent any dirt or scurf which may happen to pass the skimmer from entering the mould with the metal. As long as the basin is full, the dirt floating on the surface will not be carried into the ingate. For a similar reason the surface *area* of the depressed portion is made sufficiently large. If it were small it would not hold much metal, and the scurf would be more likely to become sucked into the ingate.

These pouring basins are made chiefly by hand. A small middle flask, or a frame only, is laid upon the cope, and swabbed with clay water, the runner pin put in place, the sand rammed with a pegging rammer, central portions dug out and then rounded and moulded to the proper form with the hands. All sharp corners which might become washed down by the rush or pressure of metal are scrupulously avoided.

In spite of every precaution in the manner of pouring, particles of dirt which accumulate from the metal in the ladle, and from the sand in the basin, gain access to the mould. In castings which are not turned or

planed, the slight contamination thus caused is not of importance; but on turned or planed faces the slightest specks have an unsightly appearance, and in such work various devices are made use of to obtain the cleanest faces possible.

In steam and hydraulic cylinders, in pumps, and work of this class, a belt of **head metal** is cast on, into which the lighter matters rise, and this is subsequently turned off. On large flat upper surfaces an extra thickness of metal is allowed, to be planed off afterwards. Or several *risers* are placed over the surface, and cut off. Lastly, the mode of running is modified, the metal being led in through a *skimming chamber.* This method is shown in Fig. 25. Here *B* is the ingate, and *C*, *D*, the runner. Right in the course of the runner, which is purposely made of the indirect form shown in plan, there is a capacious chamber, *A*, made by ramming up a ball in the mould. Over the chamber is a riser, *E*. As the metal obtains entry through the first portion, *C*, of the runner into the side of this chamber, *A*, it receives a rotary motion, as shown by the arrows in plan view. The effect is to throw the heavy metal to the outer part of the sphere, leaving the scurf and inferior lighter metal at and about the centre. The outer metal passes into the mould by the ingate *D*, *F*, and the lighter matters float upwards into the riser *E*. This riser need not be added in very small moulds, the chamber in itself being sufficiently capacious; but in large moulds enough dirt will accumulate to quite fill it up to the brim. Fig. 26 is drawn to show by contrast with Fig. 25 the wrong way

to make a skimming chamber. The runner entering and leaving the chamber in a *straight line, F*, there is no rotary motion set up in the metal, and the chamber is useless.

Sometimes a disc is used in the smaller moulds instead of a ball. The workmen usually speak of the employ-

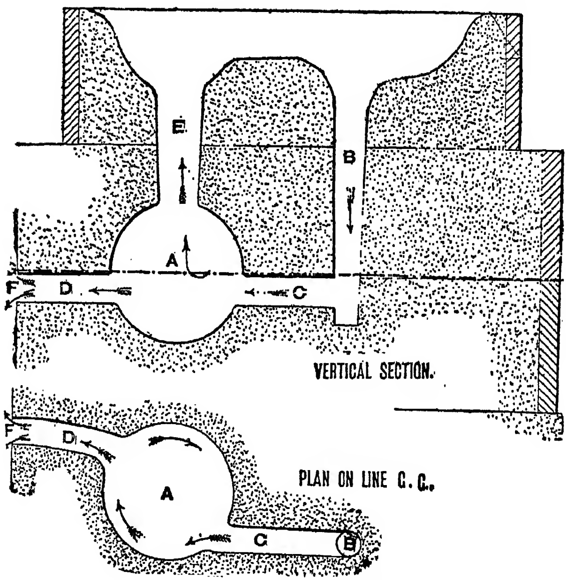


FIG. 25.—SKIMMING CHAMBER.

ment of skimming chambers as 'running with a ball' or "running with a disc."

The area of ingates should be in proportion to the size of the castings. Castings are light or heavy, thick or thin, machined or left rough, and all these points

have to be considered in determining the sizes, positions, and character of runners. Thin and light castings should be poured from several thin runners, or from a spray. Fig. 27 shows a thin **runner stick** of the type

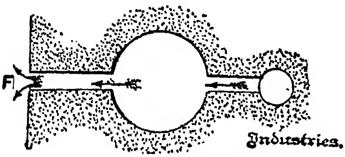


FIG. 26.—INCORRECT FORM OF SKIMMING CHAMBER.

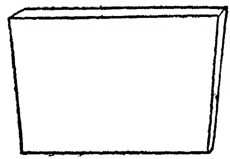


FIG. 27.—RUNNER STICK.

which is employed for pouring thin pipes, etc. A heavy runner would "draw" a light casting, and probably cause fracture. The great length of runner is given to compensate for its narrowness, a large area being necessary for quick running of thin castings. Fig. 28 shows a pattern **spray** of runners, *A*, ready for ramming *in situ*,

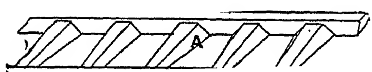
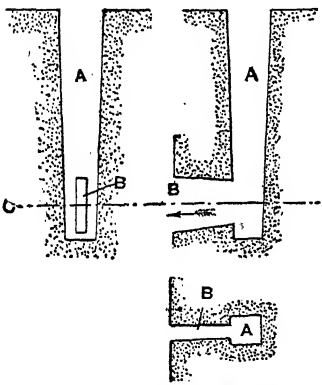


FIG. 28.—SPRAY.

against pattern *B*, also used for the pouring of thin light castings, the total area of entry being large, while the spray itself is readily detachable after casting. Although heavy castings will require runners of large area, it is better, as far as practicable, to employ several runners of moderate area rather than one or two of

FIG. 29. RUNNER STICK.

large size. Thus the runner pin shown in Fig. 29, which is the most common form, is not so good as the oblong ones in Figs. 30 to 32, being liable to cause a "draw" in its immediate vicinity. Runners of circular section are most often used, but those of flat and oblong section are in many, perhaps in most cases, preferable



SECTION ON LINE. C. C.

FIG. 30.

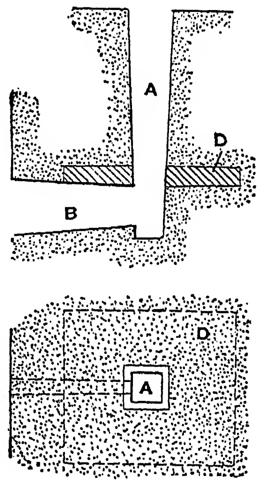


FIG. 31.

INGATES AND RUNNERS.

to the round ones, because they are more easily and safely knocked off and chipped from the casting. There must in any case be sufficient area, because a casting poured too slowly will probably show "cold shorts," that is, imperfect union of the metal in some sections. A mould poured too rapidly will become unduly

strained, and perhaps blown and scabbed. A light thin casting cannot be poured too rapidly or the metal be too hot; a heavy casting must be poured slowly, and the metal must be "dead."

In cases where castings have to be machined the runners should be kept as far away as possible from the machined parts, as the metal is always dirty and spongy in the immediate vicinity of a runner.

Figs. 30 to 32 illustrate two examples of running at the side of a mould. In each case *A* is the ingate and *B* the runner. The pattern ingate, and the pattern runner are each rammed up in place, and the runner *B*, in Fig. 30, is then withdrawn into the mould in the direction of the arrow. In Fig. 32 the runner stick is drawn in the opposite direction, the sand being temporarily dug away behind for the purpose. Fig. 31 shows a loam cake, *D*, rammed in the mould, being better adapted than green sand in a heavy mould, to withstand the cutting action of the iron as it passes from *A* into *B*.

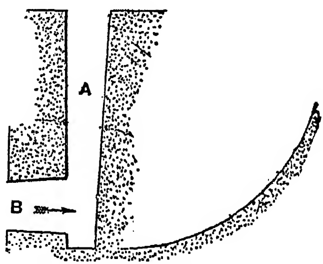


FIG. 32.—INGATE AND RUNNER.

By a **draw**, we mean that, in a material so contractile as iron, the sum total of shrinkage will be greatest where the greatest mass of metal is situated. Since the outer skin becomes chilled by contact with the sand and sets first, nearly all the later shrinkage goes on within the

mass, and this naturally will produce a spongy and open casting. To prevent this, the casting is *fed*. In some cases the head cast on to receive the scurf or sullage is made sufficiently large and massive to do duty as a *feeder head*. The mass of metal which it contains must then be sufficient not only to remain liquid until after the metal in the mould has set, but also to exert considerable pressure upon the mould, feeding and consolidating at the same time. I have seen as much as 3′ 0″ of head cast on an ingot mould, but in general castings, a few inches is sufficient.

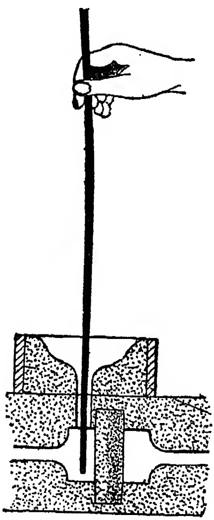


FIG. 33.—FEEDING.

A **feeder head** proper, however, is distinct from head metal, consisting of a basin or cup of metal somewhat like a pouring basin, in fact a pouring basin is often utilized as a feeder head, as in Fig. 33. A feeder head must be placed directly over that particular portion, boss, lug, etc., the shrinkage of whose mass it is intended to compensate, and its capacity must be so great that its metal shall remain fluid after that in the boss, lug, etc., has set.

The **feeding** or **pumping** is performed by getting a $\frac{1}{4}''$ or $\frac{3}{8}''$ iron rod red hot in the molten metal in the ladle, and immediately the pouring has taken place the rod is inserted into the feeder head, Fig. 33, and a vertical up-

and-down movement of the rod in the metal is commenced, taking care not to touch the actual mould. The effect is to create an agitation or movement in the molten metal, and to keep a passage clear into the heavy and still molten central mass, in order that until it becomes actually set, fresh and ample supplies of hot metal shall enter from the feeder head to compensate for the loss due to interior shrinkage. In large masses it is necessary to supply added hot metal from a hand ladle to the feeder head. The pumping continues until the metal thickens and clings to the rod, when the latter is struck sharply with a bar of iron or hammer to effect the detachment of the clinging portions. Finally the metal becomes so viscous that little more shrinkage will take place, and the feeding ceases.

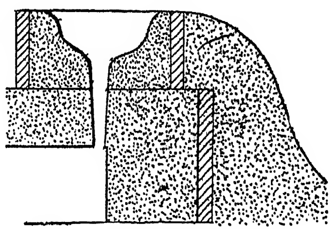


FIG. 34.—FLOW-OFF GATE.

In moulds of considerable area, **risers** or **flow off gates** are employed. Their function is mainly to relieve the cope of excessive strain, which in their absence would cause injury to the mould. There is an enormous pressure on a cope of several square feet in area, and though the flasks are made stiff and strong, and well loaded, this pressure would, and often does, cause a thickening of the central portions of the castings to an extent of $\frac{1}{4}''$ or $\frac{3}{8}''$, due to the rising up or springing of the cope under pressure. Risers relieve it partly, though not entirely, of pres-

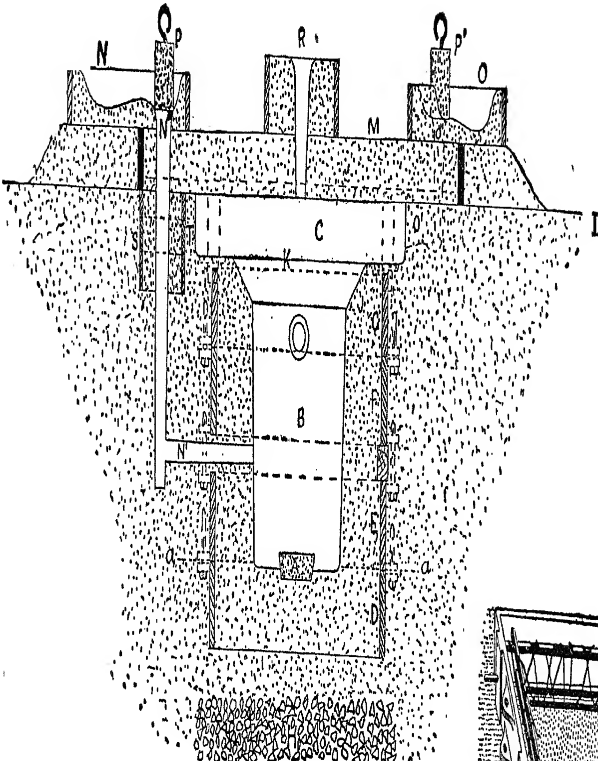
sure, but they also allow of free exit of the air and gas, which would otherwise be confined in the mould, and cause scabbing. The risers should properly be kept closed with plugs of clay or sand until the mould is just upon the point of filling, when the plugs are instantly removed, and the pouring still continuing, the excess of metal is allowed to flow off quietly outside the flask. Fig. 34 shows one of these flow off gates, the metal flowing away over the sloping bank of sand.

CHAPTER V.

GREEN SAND MOULDING. PART II.

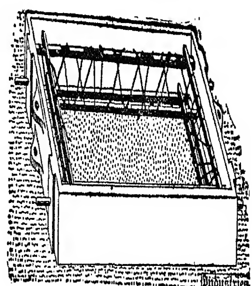
We are now in a position to consider two or three examples of green sand moulding of a more advanced character than those illustrated in the last chapter,—moulds involving a much higher degree of skill, and affording good illustrations of the varied and ever changing work which calls forth the best judgment of the jobbing moulder. Figs. 35, 36, 37, are illustrations of the mould made for an **anvil block** of four tons weight. It is an example of a deep and heavy mould. This is not a case of bedding in pure and simple, but illustrates the manner in which methods are modified in order to suit individual and special jobs.

To begin, the top of the block must be sound, and that is therefore cast in the bottom. It is a deep mould, and there is a core, *A*, in the bottom for the anvil, which at that depth would be very awkward to set in place; there is also a great discrepancy in the dimensions of the smaller part of the block *B*, on which the anvil rests, and the base *C*, which is embedded in the concrete. For these reasons the method of making the mould which is



VERTICAL SECTION Y—Y.

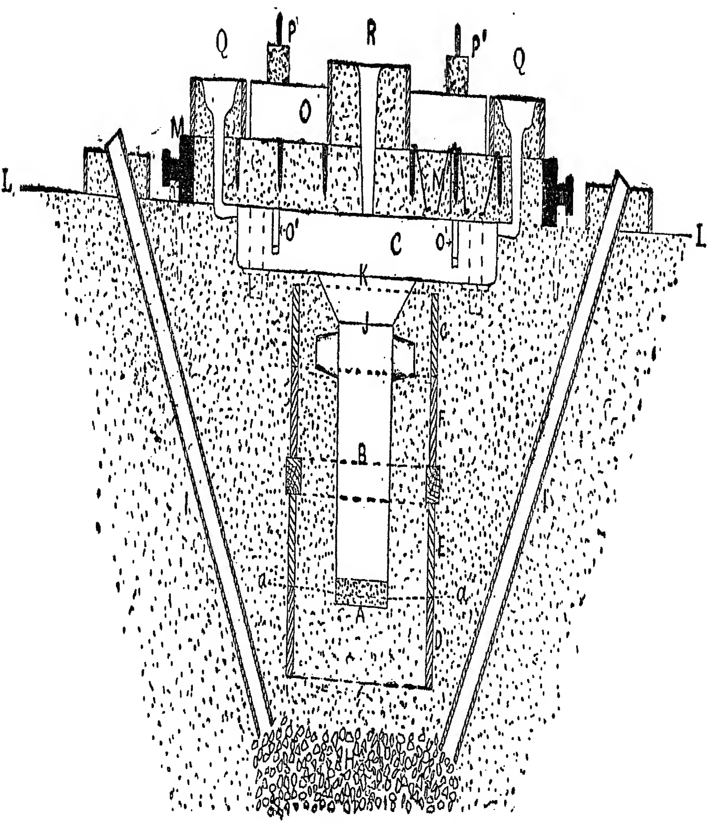
FIG. 35.—MOULD FOR ANVIL BLOCK.



RODDING AND LIFTERING.

here shown was adopted. The whole of the stem *B* was made in flasks in dry sand. The method of supporting the sand in middle flasks by means of rods and lifters is shown in perspective on the right of Fig. 35. The flask *D* was parted from *E* at the joint *a, a*, for convenience of placing the core *A* in position, but *E, F, G* were permanently cottared together to form one "middle." Blocks of wood were necessarily interposed between *E* and *F*, to allow of the entrance of the runner *N′* to the mould. This portion of the mould was made, dried, cored, and finished first. Then a pit was dug in the foundry floor, a coke bed, *H*, laid down at the proper depth, sand rammed and vented over it, and the flasks *D, E, F, G* all cottared together, were bedded down level thereon, their vents passing down to the coke bed *H*, and thence out through the vent pipes *I*, which are rough pieces of cast iron pipe of three or four inches diameter, reaching from the bed to the surface of the floor. The space encircling the flasks was then filled with sand, and flat-rammed level with the top edge *L*. The pattern being made to join at *J* and at *K*, as a matter of convenience, the portion from *J* to *K* was placed back in the mould, and the base *C*, dowelled by the face *K*, was laid in position for ramming, which ramming was continued to the top edge *L*.

The cope *M* being perfectly plain was not rammed in place, but upon a levelled bed of hard sand, being liftered and vented all over its depth and area. A few lifters depending from their bars are shown in section at *M′*, to illustrate the method of liftering. While the vents from

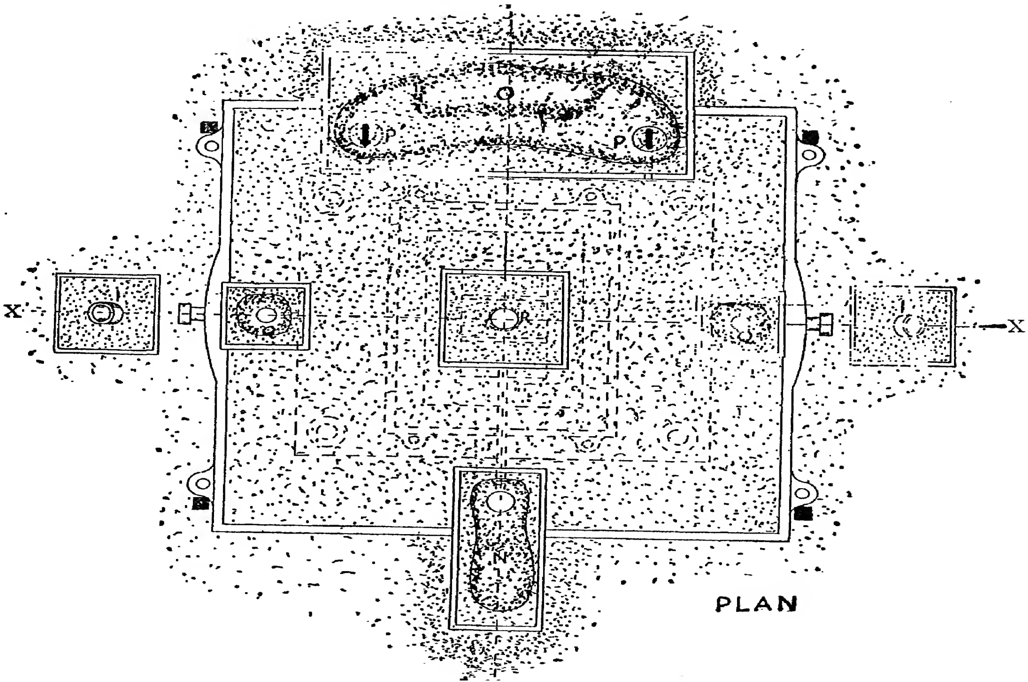


VERTICAL SECTION X—X.

FIG. 36.—MOULD FOR ANVIL BLOCK.

the stem *B* go down into the coke bed *H*, those from the base *C* pass out through the cope *M*.

The manner of pouring was as follows. There was one pouring basin, *N*, for running near the bottom, one, *O*, for the main running at the top. The purpose of the runner *N′* is simply to partly fill the mould so that the metal falling from the top at *O′* shall not cut up the sand, but fall into a pool of metal. A four ton ladle was used at *O*, and a one ton at *N*, thus allowing a ton for heads and basins. The pouring commenced at *O*, but merely to steady the ladle in position, and fill the hollow, *O*, of the basin. As soon as this was done, the ladle at *N* was poured, the plug *P* being kept in place until the basin was nearly full, when *P* was removed, and the metal entered the mould. Immediately it had entered, the filling of pouring basin *O* began, and when nearly level, its plugs, *P′*, were removed, and the metal was run into the mould rapidly. The fact of its being filled was indicated by the flow off at the risers *Q*, whose plugs (not shown) were removed at that instant. After the cast, feeding was performed at the feeder head, *R*. The area of the runner *N′* was $3'' \times 1''$, that of *O′*, *O′*, $6'' \times 1\frac{1}{4}''$. At the opening of each ingate, *N″* and *O″*, loam cakes were imbedded in the pouring basins to sustain the pressure of the metal, sand being liable in heavy casts to become cut up and washed away. The object of the flasks *S*, enclosing the ingate *N″*, at the section where the ingate comes in very close proximity to the base, is to prevent a probable washing away of the intervening sand, *T*, which is a casualty to be guarded against.



PLAN

The pressure is in such cases enormous, and I once saw a very costly casting utterly ruined by the metal in the ingate washing away the sand, which the moulder had neglected to secure thus.

I have, to avoid confusion, shown no weights on the cope. By calculation the pressure on the cope should be as follows :—

Area of surface *C*, Figs. 35 and 36, 5′ 0″ × 4′ 6″. Height from face of cope to level of pouring basin, about 18″. Then 60″ × 54″ × 18″ = 58320″. 58320″ × ·263 = 15338 lbs. 15338 lbs. = 6 tons 18 cwt., statical load required, including cope. Actually 8 tons of weights were used.

The **Flywheel** mould shown in the succeeding figures is an example of a type of work by which the cost of pattern-making is much lessened. Instead of making a complete pattern, a process of sweeping up and of sectional moulding is adopted. It cannot properly be called bedding in, because there is no pattern, neither does it come under the head of turning over. It resembles in the main bedding in, even though there is no complete pattern used, because the work is moulded in the floor, and a cope is the only flask used. The method is one which is often adopted in heavy work of this general type, such as rectangular bed plates, and circular bases, even when the internal portions happen to be somewhat intricate intricate portions being readily formed by means of cores

A **coke-bed** should properly be laid down for this unless the rim happen to be narrow, in which case venting over the bottom, and diagonal venting therefrom to the mould joint will answer the purpose. In any case

the cope is rammed before the lower face is touched, as follows :—

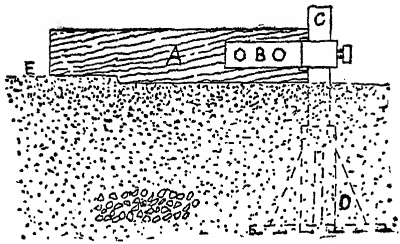


FIG. 38.—TOP STRIKING BOARD.

A bed of sand is rammed hard, and levelled with the foundry floor, and the striking board *A*, Fig. 38, is at-

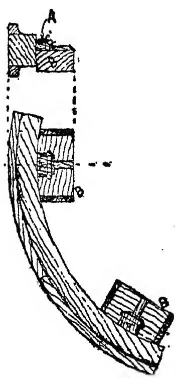


FIG. 39.—PATTERN SEGMENT.

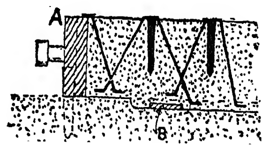


FIG. 40.—COPE.

tached to the strap *B* and striking bar *C*, whose socket *D* is bedded in the floor. By comparing the edge of this board with the pattern segment, Fig. 39, its coincidence with the edge of the segment is apparent. The board therefore strikes a reverse mould, upon which the cope, Fig. 40, is laid and rammed, a stratum of parting sand intervening.

The reason why this method is adopted, instead of striking the cope direct, is that the precise ultimate position of the cope for casting is secured thereby. If the cope were struck separately, and put in place by measurement, it would be much more troublesome to set it with accuracy than when it is rammed in place; for it is not a case of fitting of flasks with pins. The cope has to be laid upon the floor, and then the only setting which is available, is that done with stakes of iron driven into sand, Fig. 45, *D*. Returning the cope to its original position by means of the stakes with which it was set for ramming, is simpler and far more accurate than striking it first and setting it afterwards. Before the cope is rammed upon the bed several things have to be noted.

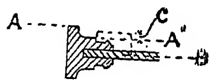


FIG. 41.—SECTION OF RIM.

Looking at the section through the flywheel rim, Fig. 41, it is clear that the formation of the face of the cope must take one of two directions, it must either coincide with the upper face, *A*, of the rim, and with the horizontal central plane, *B*, of the bosses, or it must remain entirely continuous with the rim face *A*, *A'*. The choice between the two methods is determined by the formation of the upper halves of the bosses, and of the prints which carry the arms. If the mould joint were shouldered down to be continuous with the centres, *B*, of the bosses, then Fig. 42

FIG. 42.—ALTERNATIVE JOINTING OF COPE.

would show the joint face in section, and then it is evident that as many half bosses and half prints as there are bosses and arms in the wheel would have to be laid upon the reverse sand bed struck by board *A* in Fig. 38, and in precise coincidence with the positions which the lower halves of the bosses and prints are afterwards to occupy, and that the cope would be rammed over them. It would not be easy to set these bosses correctly. Nor is it advisable to lift the cope sand away from a deep shoulder, *A*, Fig. 42, such as that against which the bosses would have to abut. Hence the reason for the adoption of the method illustrated in these figures.

The lower halves of the bosses within the rim are formed by ramming directly from the pattern segment, Fig. 39. The upper halves are made in cores. The outline of these cores is shown dotted in Fig. 41. In this case, to give sufficient sand in the core above the beading on the boss, it happens to be necessary to increase the height beyond that of the top face of the rim. This slightly complicates matters, because the thickness of core *C*, Fig. 41, standing above that face, has to enter into a corresponding print in the cope. Hence six prints of thickness *C*, and of the same length and breadth as the core, have to be measured carefully into place on the reverse bed struck by board *A*, Fig. 38, in order that their impressions may be imparted to the cope sand at the time of ramming the latter. These prints are shown in section, Fig. 40, *B*, and in plan, Fig. 43. They are set by a circle corresponding in diameter with that of the

inside of the rim, and their centre lines are brought to coincide with the intended centre lines of the arms marked upon the bed. They are prevented from becoming shifted during the process of ramming, by means of common cut nails driven down alongside of them into

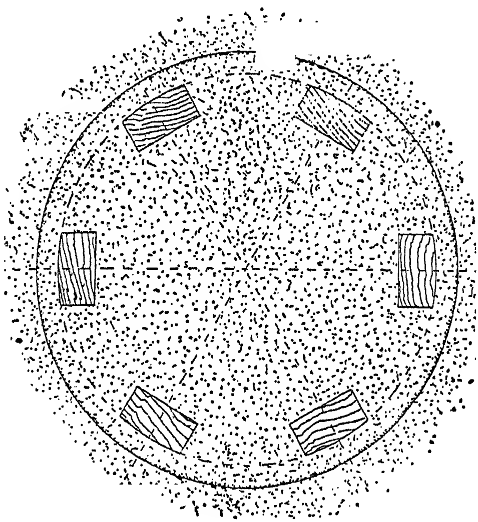


FIG. 43.—TOP PRINTS.

the sand. In this position they are rammed and their impressions obtained in the cope. The cope is liftered, Fig. 40, rammed, and vented precisely as though it were above a pattern, and it is then lifted off, taken away, turned over, and any broken edges mended up.

Then the second striking board *B*, Fig. 44, is bolted to the strap at such a height that its joint edge *A* coin-

cides with the joint edge *E* in Fig. 38. The lower edge *C* coincides with the lower face of the rim, so forming the bed upon which the pattern segment, Fig. 39, is to rest. The corner *D* coincides with the external diameter of the rim, as shown dotted; or it may, if preferred, be of a larger diameter. The edge of which *D* is the termination is made diagonal, because if made perpendicular the sand would tumble down—being made as it is, the segment pattern, Fig. 39, rests upon the bed struck by *C*, and

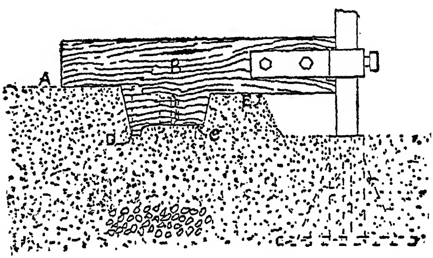


FIG. 44.—BOTTOM STRIKING BOARD.

the sand is rammed both on the external and internal sweeped faces of the segmental pattern. The position which the segment has to occupy in relation to the swept up bed is shown by its dotted outline given in the figure. The edge *E*, it will be seen, corresponds with the upper face of the rim.

The bed is made as though for a bedded-in mould. The sand is rammed hard in the lower portions and well vented, and the vents closed with the fingers. A more open stratum of about an inch in thickness is lightly

rammed over this surface and consolidated with the fingers, the board being swept around several times until an evenly rammed, well-vented, and smooth bed underneath those portions which will be occupied with the rim, and to a little distance without and within the

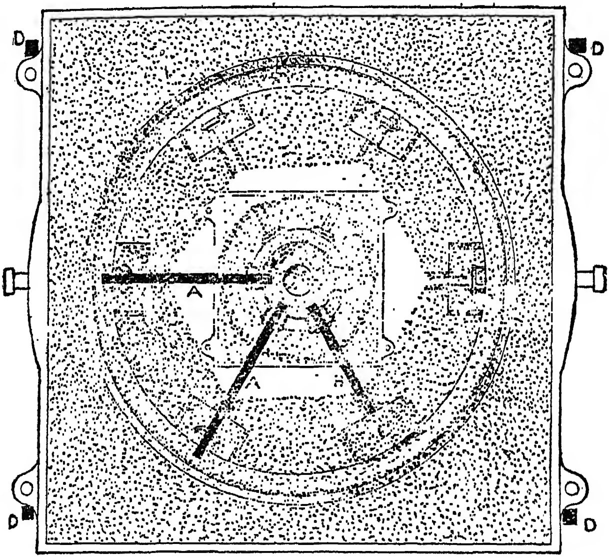


FIG. 45.—PLAN OF MOULD.

same, is produced. Then the board is removed and the pattern segment laid down for ramming. This segment, Fig. 39, has the same section as the rim. Two half bosses, *A*, *A*, are fastened upon it very exactly at one-sixth of the circumference. Prints *B*, *B* occupy the positions of the complementary halves. Ample taper is

given to these prints, as shown. The segment is laid in the position seen dotted in Fig. 44, and rammed. The circumferential position of the segment at each remove is governed by the bosses, the boss near one end being dropped into the impression just made by its fellow at the end opposite. The precise length of the segment extending beyond the bosses is not of importance. It is

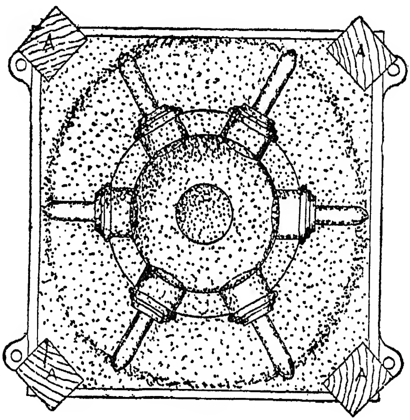


FIG. 46.—BOSS MOULD.

not at all necessary to ram the sand over the whole of the internal area, but only sufficiently far inwards to afford a backing for the rim mould, and for the bosses and their prints. This is seen in Fig. 45. At, and near the centre also, a space must be left for the small flask containing the boss mould.

We now leave the rim for awhile, to note the preparation of the boss. This is rammed from a complete pattern

in a small flask by itself. Fig. 46 shows the joint face of the lower half of this flask in plan. As the arms which are cast in, have to come through the flask joints, these joints are left open to an amount sufficient for that purpose, blocks of wood, *A*, being inserted at the corners at the time of ramming, to keep the flasks the required distance apart. The sand therefore stands above the joint faces of the flasks in both top and bottom parts, reaching to the centre of the arms. This explains the reason of the sloping joint indicated by the shading. The ramming up is quite simple, and is done in dry sand.

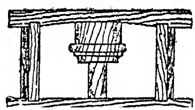


Fig. 47.—Core Box.

After the boss mould is dried, it is set in the centre of the rim mould, Fig. 45, its position being checked both radially and horizontally, the rule, straightedge, and spirit-level being used, and the print impressions for the arms in rim and boss are all brought in line.

The cores which form the upper halves of the bosses are made in the box, Fig. 47.

The arms are formed of malleable iron bar cut off in suitable lengths, and either jagged, or fullered, Fig. 48, near the ends, to render their hold more secure than it would be if left smooth.

Fig. 48.
Fullering of Arm.

They are now set in their places, both in the boss and rim, Fig. 45, *A*, *A* showing the relative positions of arms and mould at this precise stage. All being thus set in, the cores forming the top halves of the bosses are laid in

their prints, Fig. 45, one, *C*, being shown in place over arm *B*. Then the cope being returned to the position in which it was rammed, by means of the guidance afforded by the stakes, Fig. 45, *D*, these cores are confined securely, their upper portions, of the thickness *C* in Fig. 41, entering into the impressions formed by the prints in Fig. 40, *B*, and in Fig. 43. This particular example illustrates a 7′ 0″ fly wheel, of 14 cwt., and six tons of weights were used on the cope. The pouring took place at two basins, and the metal was fed at four risers.

The casting of the boss must not be done at the same time as that of the rim. If it were, the boss being small would cool at once, and, setting firmly, oppose the inward shrinkage of the rim by setting up the resistance of the rigid arms thereto; and the consequence would be that, since shrinkage must occur somewhere, the rim would become fractured. In this case the rim was cast twenty-four hours before the boss, and when its shrinkage had very nearly ceased the boss was poured. It was both poured and fed through the ingate.

CHAPTER VI.

DRY SAND MOULDING.

WHETHER the metal is poured into green sand or dry sand does not affect the essential methods of moulding adopted, since the same processes of turning over, liftering, rodding, and sprigging are employed in each case. Instead of selecting any special example therefore for illustration, I will simply point out in a few paragraphs the broad differences between moulding in the two classes. The class of work done by each method, and the mixtures of sand used, are essentially different. Heavy work, and work which is wanted specially sound and free from blow-holes, is cast in dried moulds. Strong mixtures of sand alone can be dried. See Appendix.

A dried sand mould must be **dry.** This may seem a needless truism, but the point is one of very great importance. Since the mould depends for its venting on its porosity, the presence of moisture even in small quantity implies that the sand is still close and dense.

If green sand mixtures were dried in the stove, they would pulverize and fall to pieces. And the strong

mixtures also which are used for dried moulds, though hard and sufficiently firm to resist great pressure of metal, are very tender when edges are concerned. For this reason the joint edges of such moulds are always **finned**, that is, their immediate faces are pressed down with the trowel while the mould is yet green, so that when the joints are brought together the edges remain slightly asunder, like Fig. 49, *A*. A fin or thin film of metal of course forms here, but this is of no consequence; while, on the other hand, a crushed joint edge with the consequent falling of the sand into the mould would, if extensive, result in a waster casting.

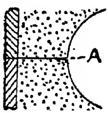


FIG. 49.
FINNED JOINT.

Another point to be noted in connection with dried sand moulds is, that they will bear harder ramming than those in green sand, since they become porous in drying. For the same reason, less venting with the wire is required. The very close nature of the sand demands that its venting be perfect, and it can only be properly vented by the drying out of the moisture, and the carbonization and desiccation of the hay in the horse-dung. As long as steam, even in small quantity, is seen coming from the mould, pouring is unsafe, and the mould should properly be returned to the stove. But a steaming mould poured while warm, that is, soon after removal from the stove, is less risky than one which is allowed to become cold first. There is also this advantage in the use of dry sand, that less gas is generated than in moulds made in green sand. This

is a consideration in large moulds involving a great deal of work, because the presence of gas in quantity is apt to cause blow-holes and scabs, and any arrangement by which its amount can be reduced is a distinct advantage.

Dried sand moulds will also bear more swabbing than those in green sand. Too much moisture in green sand is always a source of danger. But the swab may be used freely in dry sand, and this is often advantageous at the time of withdrawal of the pattern or of mending up, and the heat of the drying stove removes the moisture.

As in green sand moulding, so in dry, stronger facing mixtures are used in the vicinity of the pattern than in the body of the mould. The floor sand, either alone or mixed with slight proportions of stronger sand, is used for mere box filling. The cost of dry sand moulding is in excess of that done in green sand because of the extra cost of coke for drying. But this depends partly upon the system of the shop. When drying is extensively employed the percentage of expense is comparatively small, especially when the superiority of the castings and the lower ratio of wasters is taken into account.

CHAPTER VII.

CORES.

THE term **core**, used in a general way at least, is almost self explanatory. Any central portion, or a portion removed from central parts, is a core. But in Foundry work the term has several distinct meanings, defined by the prefixes, "green sand" core, "dry sand" core, "loam" core, "chilling" core.

The term "**green sand core**" simply denotes the central portions of those moulds which are made directly from the pattern itself, without the aid of a core box. Thus, the central portion of a plain open rectangular frame, like the surface boxes used for hydrants in the streets, would yield a green sand core, because moulded from the pattern itself, and the sand employed would be of precisely the same character as that encircling the pattern, and would be connected therewith by rods, nails, or grids, and undergo no process of drying whatever. These portions, though termed cores (often termed *cods* also), do not come properly under the present heading. Metal cores for chilling the holes in the hubs or bosses of wheels may also be disregarded in this connection, and also

those loam cores which are bricked up, see Chapter VIII., so that all we have to consider in this chapter is cores made in dry sand in core boxes, and loam cores which are "struck up" on core bars.

Cores are required when (*a*) there would be extreme difficulty in so constructing a pattern that an impression could be taken of the central portions, except by necessitating a large number of joints in pattern and mould; (*b*) when the central sand would be so weak that it would not retain its form and position against the rush and pressure of metal; (*c*) when the cutting out of the internal portions of patterns would render them excessively weak as patterns; and (*d*) generally, when it would either be impossible or extremely difficult to make or put the mould together, or vent it without the aid of cores. Thus, if we take almost any pump clack box or valve box with seatings we could make a pattern precisely like the casting, making as many joints as would be required to allow of drawing the parts separately from the mould. But we should then meet difficulty (*a*) and also (*c*). But the substitution of a simple core or cores enables us both to make a strong pattern, and to employ one or two joints only, instead of several, in the mould. Or, if holes of small area, but of considerable length, are required in castings, the green sand would not deliver freely from similar holes made in the pattern, but would become cracked and broken away, even if a considerable amount of taper were imparted; neither would they withstand the rush of metal. Then the conditions (*b*) necessitate the use of dry hard cores. And no more familiar ex-

ample of condition (*d*) could be given than that of any engine cylinder with its passages and feet, and often other attachments beside.

It is clear that the same conditions must exist in cores as in the moulds themselves. The substance of cores must be stiffened with rods, grids, or nails, precisely on the same principles as moulds, though the conditions and details are somewhat different. Vents of sufficient area must be provided to carry off gas and air, and the cores must be secured against the pressure of liquid metal. These are all points of fundamental importance, and we will consider them in detail.

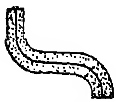


FIG. 50.—STEAM PASSAGE CORE.

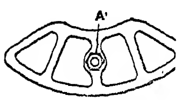


FIG. 51.—A GRID.

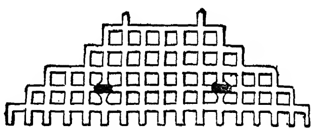


FIG. 52.—A GRID.

And first, in regard to the stiffening of cores. In a plain round core made in a box, a rod of iron is rammed up with it, and this is the simplest plan. In crooked cores the rods are either bent, as in Fig. 50, which illustrates the passage core of an engine cylinder, or grids are formed of wires or rods fastened together with solder. In large cores, grids are always used, like Figs. 51, 52, having nuts or eyes by which to lift them. These grids may be of any outline, being adapted to their cores. Fig. 51 shows one of a sweeped outline adapted to a sweeped core,

Fig. 52 one of triangular outline; Fig. 51 has a nut, *A*, cast in to take the screw used for lifting, Fig. 52 has a couple of eyes cast in for the same purpose. These are usually cast in open sand, the moulder using a standard pattern grid, having excess of length, and stopping it off to length and outline required. In large and intricate work several distinct grids may be bolted together, the bolts being so placed that they may be readily taken out after the casting is made, through openings in the cored out sides of the casting itself.

Fig. 53 shows a grid used for a pipe core made in a core box, a grid being used in each half core, and Fig. 76, p. 109, one used for a bend pipe of large diameter, the longitudinal portion stiffening the core, and the offsets or prongs giving local support to the sand. Stiffeners and grids of this kind are used for cores rammed in core boxes, and for those strickled up on plates. But there is a large class of cores which are not made in boxes, but struck up on revolving bars. The bars then act as stiffeners longitudinally, and the core is made in **loam**, whose adhesion to the bar is assisted by the use of hay bands, or hay ropes twisted and wound around the bar. When cores are very large the bar is not increased directly in proportion, except for certain standard work to be noted presently, but is selected simply with a view to sufficient stiffness, and the size of the core is increased by the addition of hay

FIG. 53.—PIPE GRID.

bands and loam alternating with each other, and sustained with core plates *A*, Fig. 54. In standard pipe and column work, collapsible core bars are used, these being then only a trifle smaller than the core, say about an inch, and made in segments in such a manner that the knocking away of a key allows the segments to collapse, or fall inwards towards one another after the casting is

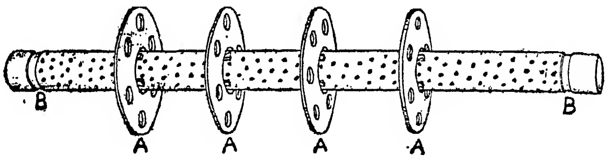
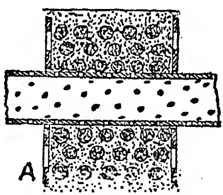


FIG. 54.—CORE BAR AND PLATES.



SECTION THROUGH FINISHED CORE.

made,—the bar then being readily removable from the casting.

There is thus a very wide range in the size and character of the bars employed. The smaller ones are made of gas piping; for those over about 3″ in diameter, cast iron cylinders are employed, and these may be either parallel or tapered, according to the character of the work. The bars are invariably hollow, and pierced with

numerous small holes, Fig. 54, for the air vents, which pass from the encircling core through the holes to the interior of the bar, whence they find exit at the ends. The bars are turned next the ends, Fig. 54, *B*, to form journals, which revolve in vees on the cast iron trestles used for their support. A boy turns at a winch handle inserted in one end of the bar, while the core maker winds on the hay bands, and daubs the loam. This is work requiring the exercise of judgment. If the bands are not pulled taut, and laid on close, and the loam well worked into the interstices, the core will "sag," or become baggy, will be out of truth, and dry unequally in different parts, and portions of the loam may flake off after drying. A layer of rope is laid on first, and stiff loam well worked over and between it as the bar revolves, then another layer of rope and more loam. The core is partially dried before putting on the final coat, which is thinner than that first applied. Fig. 55 shows a section through a core bar *A*, hay bands *B*, and finishing coat of loam *C*, *D* are the vent holes. When plates are employed, as in Fig. 54, they are cast as thin as possible, and pierced with holes, as shown, to permit of their ready fracture and withdrawal after casting. When very large, the various

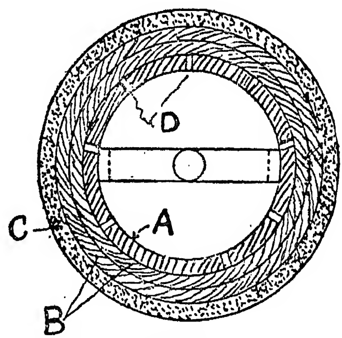


FIG. 55.—SECTION OF CORE AND BAR.

plates are, in addition to the usual fastening to the bars by means of wedges, united and stiffened with bolts passing through them all, the bolts being inserted when the final course of hay bands is being wound round, and their nuts are brought for convenience of withdrawal opposite suitable vent holes in the casting ends.

These core bars when of small diameter are used for light work, and when large, mainly for jobbing work. In regular or repetition work of large diameter, as in many pipes and columns, the cost of hay bands and of rigging up core plates would bear too great a proportion to the value of the castings. In standard pipe work therefore, and in other work of that character, the **collapsible bars** are employed. These bars are only $\frac{1}{2}''$ or $1''$ less in diameter than the finished cores which they carry, and are therefore necessarily made collapsible, that is, they are so constructed as to fold, or fall inwards, and so deliver freely from the cored holes. Much ingenuity has been displayed in their design, and several forms are in common use. It will suffice if I briefly state the general principle of their action. The shell is usually formed of three longitudinal segments of cast iron, two of which are hinged loosely upon the third or rigid piece. The movable segments are retained in their expanded condition during the making of the core, and pouring of the casting, by various devices, as by circular discs, or by wedge-shaped bars and links, adapted to similar fittings. By means of cottars, levers, and links, the movable segments are released, falling inwards after the casting is made. The body of the bar is of course pierced with

vent holes. The outside of a collapsible bar is, like an ordinary bar, left rough, the better to ensure the adhesion of the loam, which is daubed on directly, without the intervention of hay bands.

The **vents** of cores are variously contrived, and are of the first importance, since many a casting is ruined for want of proper venting and securing of the core vents.

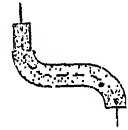


FIG. 56.—CORE STRING.

The simplest vent is that formed in a plain core by means of a rod of iron rammed therein, and withdrawn, leaving a round hole into which the air and gas generated within the core, collects, and from which it finds exit through the prints. In large cores numerous rods will be rammed in, and withdrawn thus; and in addition to these, a quantity of smaller vents will be made with the vent wire, as in making moulds. In curved cores (Figs. 56 and 57) a different method has to be adopted. **Core strings** or core ropes have to be used, being common string or rope rammed up in the core, and either withdrawn while the core is yet green, or allowed to remain in while the core is being dried; which process of baking chars the string, and allows of its fragments being blown out with the bellows. The latter method is rather uncertain, so that the better plan is to withdraw the string, the core being green, in which case two bits of wire rammed in the core, Fig. 56, prevent the string from cutting the corners by its tendency to straighten under ten-

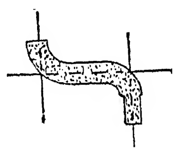


FIG. 57.—VENTING RODS IN CORE.

sion. An alternative plan which is often adopted is that shown in Fig. 57, where three straight rods are rammed up in the core, drawn out, and the core dried. Then the connection is made round the curve by filing, a string inserted, and daubed and covered over with loam. This is then dried, and the string finally withdrawn.

In the case of large cores the central portions are formed of cinders, to act as reservoirs for the air and gas, precisely as in the bulkier sections of green sand and dry sand moulds. A vent hole or holes of sufficient area is then made, connecting this body of cinders with the outer air.

In cores struck on bars, the hay is porous, and conducts the air into the central core bar, which is invariably made hollow and pierced with numerous holes for that purpose. But there is no venting done with the wire in struck up cores, as there is with those made in boxes. The latter are pierced with vent holes similarly to moulds, but the hay bands and loam are, when dried, sufficiently porous of themselves.

Cores are **fastened** and their vents secured in several different ways. In most cases they are set in *print* impressions, but not invariably. If a core is large and heavy, prints are not necessary. Still, in the vast majority of cases they are employed.

The **forms of prints** are various, depending on the position, and mode of support required. Cores may rest in the bottom of a mould, or be carried in the top, or at the sides, or be bridged across from one portion to another. They may be carried by print impressions made in other

cores. A core may be carried by one print only, or it may have several points of support.

Generally the rule is this. A core laid in the bottom is sustained by the bottom print only, the exception occurring when the core is so long relatively to its area that a bottom print alone would not afford it sufficient steadiness of base. In that case a top print will be used, or chaplet nails, or perhaps both in combination. But if the core, though long, has a broad base sufficient to afford steadiness, then neither top print nor chaplet nails are required. A core carried at the side, if short

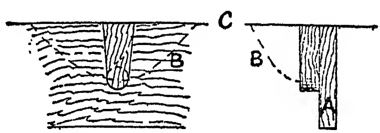


FIG. 58.—POCKET PRINT.

relatively to its area, will need no other support than the side print. If long, it also must be supported by chaplet nails, or if it passes right across a mould, by a print on each side. Cores carried at the sides may be either sustained by prints of the same kind as those used in top and bottom, or in **pocket prints**, dependent on circumstances. Pocket prints are used when the joint of the mould does not coincide with the centre of the hole. In such a case as Fig. 58, if a round print were used it would have to be skewered on loosely, and the core thrust in afterwards, which in this case could not be done, the core being unable to pass down *A*; or the cope

sand would have to be jointed down around the dotted line *B*, to the centre of the print, which in deep or in moderately deep lifts would be very inconvenient. Using a pocket, or " drop print," the lift takes place to the cope joint *C*, leaving a clear open space into which to drop the core, which is then filled over with sand, a stopping over board, Fig. 59, *A*, cut to clip the core, being held against the mould face while the space, *B*, above the core is rammed with sand. The core is then permanently secured as though in a round print. But core setting embraces very much besides this. It is not always

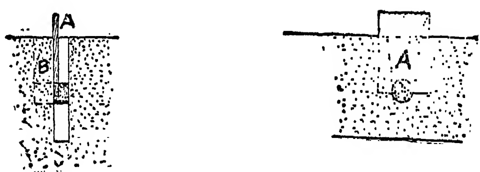


FIG. 59.—STOPPING OVER.

sufficient in large cores to trust to the pressure of contiguous sand for security. There is an enormous liquid pressure in large moulds, and this would, in the absence of due precautions, force the cores bodily out of place in their central portions, even if well secured at the ends in their prints ; or would carry them away from their prints if simply laid therein. A pipe core or column core, for example, would be bent and curved upwards until it would nearly or quite touch the top of the mould. A flat core with metal over its top face, and having therefore open space between it and the cope

sand, would be floated up by the metal, and make a waster casting. **Chaplet nails, chaplets,** and **stops** are therefore employed to steady cores in their proper positions. The forms and sizes of these vary with their position and function. Figs. 60-67 show chaplets *in situ*. In Fig. 60, *B'*, is a chaplet nail driven into a block of wood, *A'*, to afford breadth and steadiness of base in the yielding sand. The height of this nail is adjusted to the thickness, *B*, of metal required. Upon the flat head, *C'*, of the nail rests the core, *C*. Fig. 61 shows another chaplet made by riveting a bit of iron rod, *B'*, into a flat plate, *A'*,

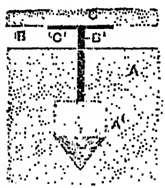


FIG. 60.—CHAPLET.

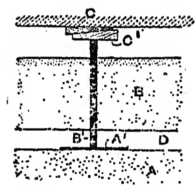


FIG. 61.—CHAPLET.

and used for a heavier class of work than the common chaplet nail. Here *A* is the core whose upward thrust is sustained by the flat, *A'*, of the chaplet, which passes through the cope sand, *B*, being supported either against the inside face of a flat bar of the flask, or a bar of iron, *C*, placed temporarily across, as shown, to fulfil the same purpose. *D* is the thickness of metal between the upper face of the core, *A*, and the lower face of the cope, *B*. Fig. 62 shows another chaplet which lies entirely between core and mould faces, and whose thickness is equal to the thickness, *A*, of the metal. In

large heavy moulds these chaplets will be of correspondingly large area, so that two or three stalks may be required to connect the plates, Fig. 63. In light work not subject to much pressure, spring chaplets are used, consisting of pieces of hoop iron bent round. These are

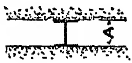


FIG. 62. CHAPLET.

FIG. 63.—TRIPLE STUD CHAPLET.

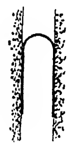


FIG. 64.—SPRING CHAPLET.

retained in place by their elasticity, and are mostly used against vertical or nearly vertical faces, Fig. 64.

Chaplets have their faces curved when they abut against curved faces. Figs. 65, 66, show two such forms, modifications of Figs. 60, 61. The core rests upon the

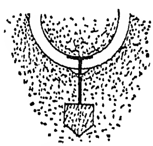


FIG. 65.—PIPE CHAPLET.

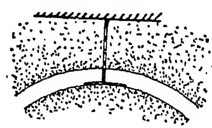


FIG. 66.—PIPE CHAPLET.

FIG. 67.—STOP.

stud in Fig. 65, but in Fig. 66 the stud is introduced to resist the upward pressure of the core. Fig. 67 shows a stop employed when the mould is subject to very great pressure. It is made of cast or wrought iron, and turned bright, or ground.

The evil of stops and chaplets is their tendency to cause blow holes in their vicinity. Should they become rusty the mould is absolutely certain to blow very badly, owing to the formation of gaseous compounds from the rust. Chaplet nails are often tinned to prevent rust. With the same object wrought iron chaplets, made by the foundry smith, are heated to redness in the fire and brushed over with tar or oil. Oil is also poured around and over chaplets while in place to prevent formation of rust during the time intervening before casting, and to cause the iron to lie quietly on the cold metal. In all but the thinnest castings the chaplet stalks become more or less fused by the metal surrounding them. But the heads usually remain visible, and do not amalgamate properly. Hence chaplets should never, if it can be avoided, be placed against faces or parts which have to be bored or turned.

It is not only necessary to fix and properly vent cores, but to **secure the vents** as well, that is, to see that due and adequate provision is made for the escape of the air and gas from the interior of the core to the outer atmosphere. The vent openings must be so secured that there shall be no chance of the entry of the molten metal into them. If the metal gets in, the gas will not get out, and the casting will blow, and become a "waster." A chapter could well be entirely devoted to this subject of securing of vents, so important is it, and so many are the methods adopted to attain this end, but we must be content to note a few leading points bearing thereon. Thus it is risky to bring core vents off

against an abutting face simply, unless means are taken to prevent any possibility of the pressure of metal causing an opening between the faces to occur. There is less risk however in horizontal than in vertical faces, and of the two a lower horizontal face stands less risk than an upper one, because the cope is liable to, and does usually, lift slightly. Where vents are carried down through the bottom, they are taken into a coke bed, as already explained, p. 38, and thence out through a vent pipe or pipes. When they are brought into the cope, they are usually carried into one or two large holes cut through the cope sand.

But prints afford the best means of securing cores, because if any slight separation of the core and mould occurs under pressure, the metal cannot, if the core and print are mutually good-fitting, run between them into the vents. Properly the cores should be cemented into their prints by means of core sand or of black wash. This is usually done only in the most important work. In most cases it is sufficient, after the core has been thrust into its print, to press and consolidate sand around and into the joint.

When distinct cores meet each other in the mould, vents should only be carried from one into the other when they can be secured through a print impression, one thus being checked into the other. When the joint is only a butt joint, then the core vents must be filled with sand immediately against the abutting faces, and the air be brought away at the opposite ends where the cores fit the print impressions of the mould itself.

In the case of cores struck upon revolving core bars, the air, after being brought into the bars, is carried out at the ends.

Cores are **dried in stoves** or ovens heated with coke fires. The smaller cores are dried in ovens having a capacity of a few cubic feet only; for the larger ones, stoves of from 18′ to 24′ long, 10′ to 14′ wide, and 10′ to 12′ in height, are employed. These are built of brick-work, and furnished with folding or sliding doors. The cores are laid upon a core carriage, which is a low iron carriage running on tram rails, and provided with suitable supports for the ends of the core bars, and with flat plates for cores made in boxes, and those formed with strickles. A temperature of about 400° is suitable for the drying of cores; excess of heat burns the hay, and makes the sand or loam rotten and friable.

CHAPTER VIII.

LOAM WORK.

THE advantage of **loam moulding** consists in the facilities which it affords for making castings of the most massive character without incurring much expense for pattern making. The apparatus used is of the most simple description, consisting of spindle, bar, and striking boards; the materials being loam, bricks, and cinders: with the aid of these the largest and heaviest castings are made.

Loam work is quite a specialized branch, which all moulders have not had an opportunity of acquiring, hence its exclusiveness; but it is not more intrinsically difficult than the other branches. I am inclined to think it easier of acquisition; but here, as in many other instances, the question is one of supply and demand, rather than of special difficulty. Also, large loam moulds are costly, and men are paid then for their care, as well as skill and special knowledge. The mould for a condenser, or for a large cylinder, will often occupy a couple or three men for nearly a month, hence the matter of two or three days' time, more or less, is of

small account in comparison with the soundness of the casting.

The art of loam moulding, after the first principles are mastered, lies in the exercise of the inventive faculty, the ability to scheme the best methods, to elaborate the safest, and on the whole the cheapest tackle: to conceive the main plan, and to execute the lesser details with a clear head, guided by the lessons born of experience. Loam moulding is an art in itself, and a man who can undertake any job, large and small, devise, and make, and rig up his tackle, and produce uniformly safe results, need never swell the ranks of the unemployed,—such a man is simply indispensable.

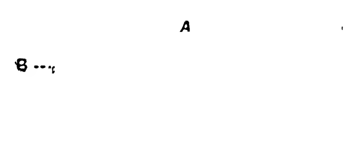


FIG. 68.—BASE FOR ENGINE CYLINDER.

It is a great advantage to a loam moulder to be able to read a drawing correctly. If he cannot do so, he has, in intricate work, to depend on the explanations of the pattern maker before he can set about his task, or even decide how to do it, or line out his centres. Some loam moulders are quite independent of the pattern maker in this respect, doing all the lining out themselves.

So much may be said about loam work, so many different cases may arise in practice, that the best way will be to take a single concrete and plain example, and make that the vehicle for our remarks on loam moulding in general.

The example selected is, Fig. 68, the base which forms

the bottom cover of the cylinder of a condensing beam engine. The top face *A*, as the casting stands when in position, is moulded and cast downwards, to ensure soundness.

The apparatus used is as follows: in Fig. 69, *A* is the striking bar, *B* its *socket*. The *socket*, of cast iron, is firmly embedded in the floor and levelled, its broad bracketed face maintaining it sufficiently steady. It is bored out to receive the turned tapered end of the bar, or it is cast around the turned tapered end, in either case making a close, yet working fit. The tapered end is long, so that as the bar revolves, its top end shall not diverge sensibly from the perpendicular. Over the bar slides freely the *strap C*, which is pinched at any required height with its set screw. To the strap is bolted the *striking board* or *loam board D*, the profile of whose edges corresponds in the main, though not in all details, with the sectional shape of the casting required. *F* is the *loam plate* or building up plate, made of cast iron in open sand moulds, see p. 31, without a pattern, by means of sweeps only.

Fig. 69 represents an early stage of operations. The socket, *B*, is set in place, the loam plate, *F*, levelled roughly on blocking pieces, *G*, or other convenient supports, the loam board, *D*, notched out to clear the boss of the strap, and the board bolted thereto. The breadth of the sides of the bar *A* is definite, being usually $1\frac{3}{4}''$, $2''$, $2\frac{1}{4}''$, or $2\frac{1}{2}''$, so that the radius of the board *D* is less than the radius of the casting by an amount equal to *H*, the radius of the bar. It is easy to see the coincidence of

PLAN.

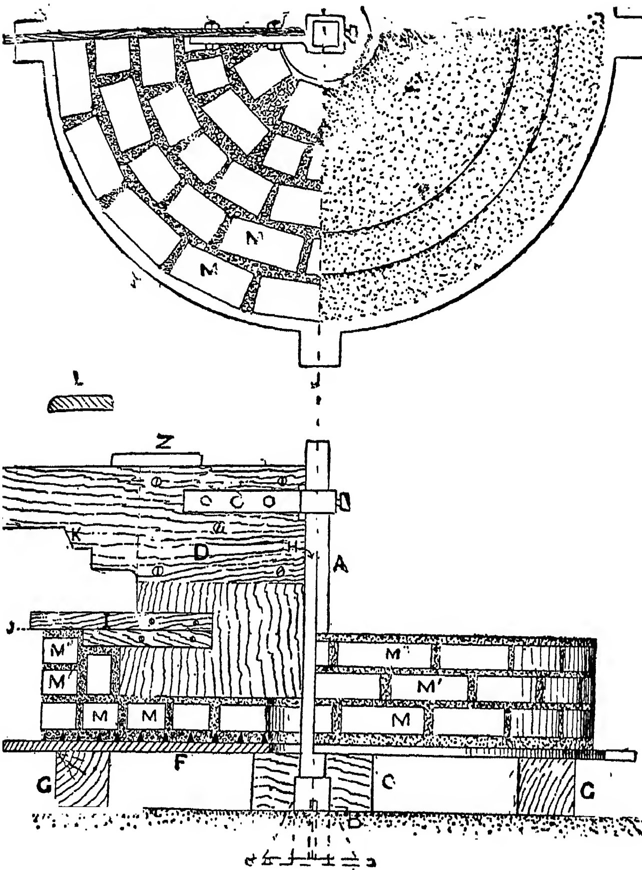


FIG. 69.—LOAM MOULDING.

the board with the outside of the casting by comparing Figs. 68, 69, the only point of difference being the strip, *I*, which is screwed on temporarily to make a parting joint, *J*, for convenience, and the step or check, *K*, which makes the top or cope joint. The edge of the board is chamfered, as shown at *L*, to avoid dragging up and tearing out of the loam. It is evident that loam boards should be truly level in order to the striking of a level mould. Hence the top edge should, in shallow moulds, be planed square with the end which abuts against the bar, and a level tried upon it, as shown at *Z*.

FIG. 70.—DIAMETER STRIP.

When moulds are deep, the bar is apt to sag at the top, and to alter the diameter. For this reason, and partly also to check any error in the cutting of the board, diameter strips and calipers are used for measurement of the mould. Fig. 70 shows the strip used for testing the interior of a mould, being made to clip the bar; and Fig. 71 the wooden calipers for the exterior. Their purpose is so obvious that they require no explanation.

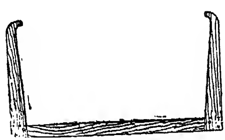


FIG. 71.—WOODEN CALIPERS.

A thin coating of stiff loam is first spread over plate *F*, Fig. 69, and upon this the bricks, *M*, *M*, are bedded. The bricking up is a vital matter, since the bricks must bind one another by being made to break joint, just as in masonry. Since moulds are irregular, and bricks pretty uniform in size, the value of the

broken bricks from previous moulds is apparent. These should be utilized as much as possible instead of breaking new bricks. It is not possible nor necessary to maintain such regularity as in masonry—the appearance of a bricked up mould is rather that of Fig. 69 (plan). In building up cylindrical work the general rule is to keep the broken bricks next the mould face, and the whole bricks as a backing. The broken bricks conduce to better venting than the whole ones would do.

When a mould is over 18″ or 24″ in depth, a cast iron ring is built in at about every six courses, to assist in binding the bricks together.

The joints of the bricks are not only wide apart, but large quantities of fine cinders are interspersed with the loam in the joints. These are introduced for the purpose of venting, which is a better and more certain method than venting with the wire, though the wire is sometimes used in some sections where the loam happens to be massed in quantity in a mould. There must be sufficient coarse loam intermixed with the ashes to bind the bricks together. The layers of brick *M′* and *M″* are then built up in like fashion, with loam and ashes intermixed. A space of about 1″ is left between the bricks and the edge of the board, and about $\frac{5}{8}$″ of this is daubed well over with stiff coarse loam—coarse loam because it affords a better vent to the gases and air, than finer and therefore closer loam. The work is then left standing for a few hours in order that the loam shall stiffen. Afterwards the final coat of loam, passed through a fine sieve, is struck on, and finished by

PLAN.

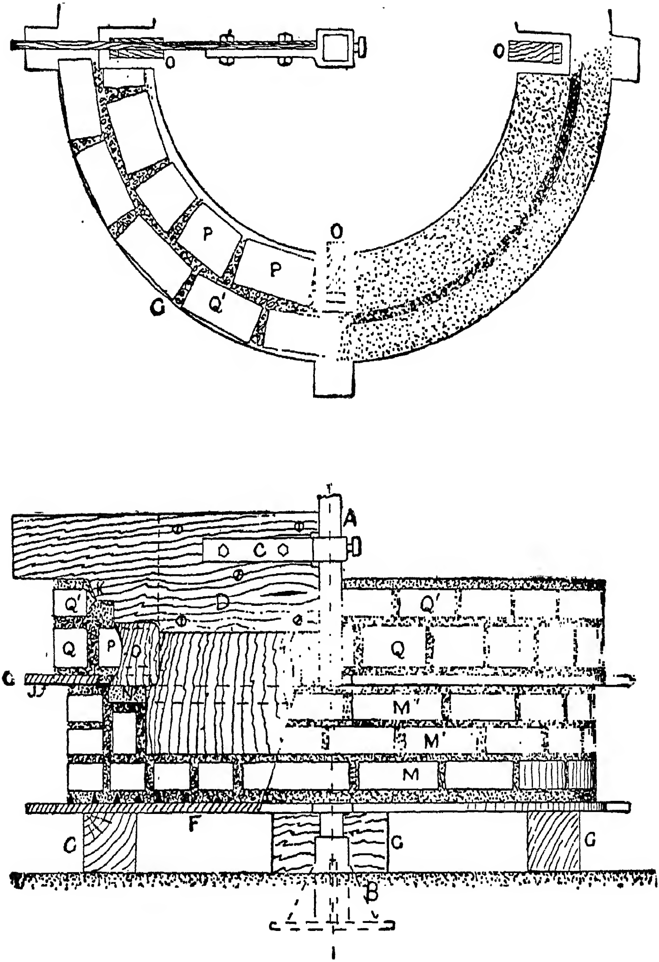


FIG. 72.—LOAM MOULDING.

the edge of the board. Several sweepings around of the board are necessary to impart the final smoothness to the surface; then the mould is put into the stove to be dried. At this stage therefore the mould is completed up to joint *J*, which coincides with the lower face of the flange *B* in Fig. 68, the mould being made, as I just now remarked, to pour the casting upside down.

Fig. 72 illustrates the next stage. A cast iron plate, *G*, is made, a thin coating of loam swept over one face and dried. The flange space *N*, already struck, as in Fig. 69, is filled up temporarily with moulding sand level with the joint *J*, and then the loamed face of *G* is turned over thereon, parting sand intervening. The strip *I*, in Fig. 69, is unscrewed from the board, and the second stage of bricking up is done on plate *G*, Fig. 72.

Sometimes ring plates are used similar to *G*, merely for the convenience of parting a mould which is too deep to go into the drying stove entire. The upper portion of the mould is then lifted off on its ring before being put into the stove, and is replaced after it has been dried. The ring is like *G*, but its function is different, *G* in Fig. 72 being necessary because the under face of flange *N* could not be struck at the same time as the lower portion of the mould in Fig. 69, without much difficulty, due to falling down of the loam.

There are four ribs, *C*, Fig. 68, cast between the flanges. These are made by imbedding four pattern ribs, *O*, Fig. 72, in corresponding positions, and spaces are cast out of the plate, *G*, to receive these. Whenever ribs, facings, brackets, flanges, which cannot be struck, occur

in loam moulds, patterns of these have to be made as in ordinary work. In some cases where the work is intricate this becomes a source of trouble to the moulder. In the first place it is not easy to set sectional portions of wood very accurately in yielding loam. Then the wood remains in the loam for several hours, more often for days, and is liable, by its distortion, to produce inaccuracy. Again, it is not so easy to secure a homogeneous face of loam by building bricks against wood as it is by striking loam upon bricks. The wood has to remain in the mould either until the loam has become stiffened or until after it has been baked in the stove. In either case the withdrawal of the wood tends to damage the mould—more when it is baked, because the loam then absorbs some of the oily matter from the wood. This makes mending up of the faces troublesome, the oily surface not taking kindly to the wet loam used in mending. In such cases the surfaces should be scraped before being mended. It is the usual practice to oil the surfaces of the woodwork imbedded in loam; but this only partially assists the stripping. The ribs in the illustration, though suggesting these remarks, are so plain that they would cause no trouble. It is in work of a more intricate character that trouble occurs.

At *P* in Fig. *72* are bricks which are made of loam, moulded into the shape of bricks, and dried. These occupy the spaces between the ribs. **Loam bricks**, as they are termed, are frequently used in moulds of this character wherever there are narrow spaces between flanges, or brackets, or ribs. One reason is, that if the

shrinkage of the casting takes place against hard unyielding bricks, the iron is liable to fracture. If loam bricks are used, they crush and yield before the shrinking metal. They have, moreover, the additional advantage of forming a good medium for venting, and this is an important point. In intricate portions of moulds it is safer to use loam bricks and an extra thickness of loam vented with the wire, than to bring the common bricks very near the surface. A thin body of loam against common bricks is always liable to become detached, and to cause scabbing by reason of the bubbling of the metal thereon.

Outside the loam bricks *P*, a layer of common bricks, *Q*, is built, and over this again another similar course *Q'*. The thickness of loam is daubed and swept over the faces of the bricks according to the profile of the board *D*.

The cope, and the central core yet remain. A plate, *R*, Fig. 73, is cast, studded over with "prods" to hold the loam which is swept over its face, as shown—the check *K* being formed to correspond with the reverse check *K* in Fig. 72—and allowed to set firmly. While it is setting, the plate *H* is partly loamed up on separate blocking. The future position of this plate is seen in Fig. 73; the arms *S*, shown at *D*, in Fig. 68, are laid in due position, and stiff loam is daubed around them, so that when this sets the arms are kept pretty rigidly in place. While the loam is setting, the work on plate *R* is continued; courses of bricks, *U*, *U*, are built upon the bed which has been already struck with the board, the joints

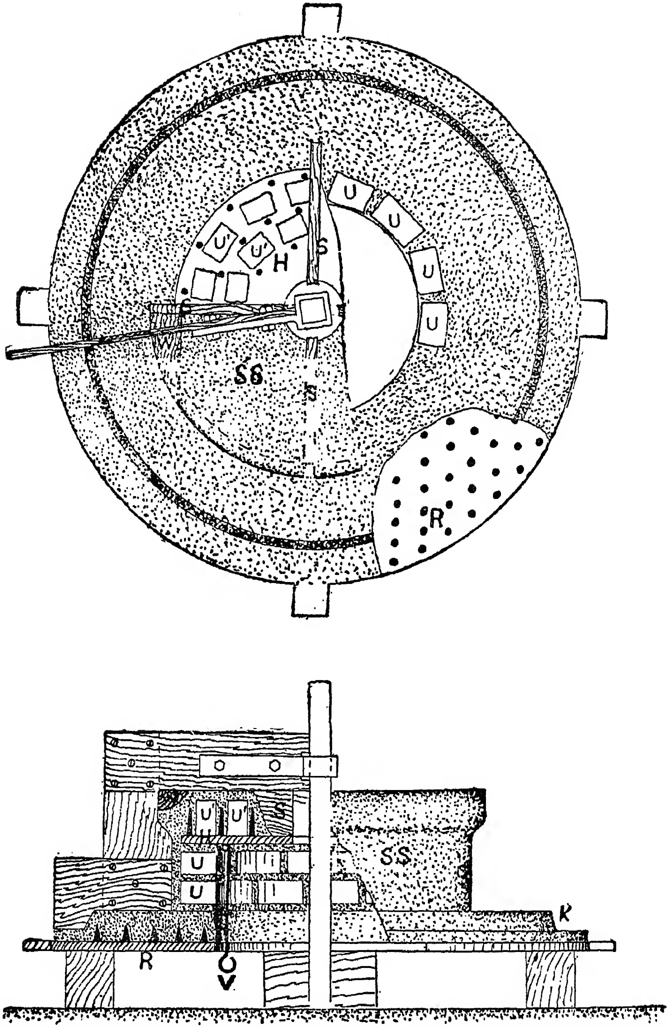


FIG. 73.—LOAM MOULDING.

being vented with cinders, or with the wire. Coarse loam is daubed around the outside, and also on the top of the uppermost layer. Then the plate, *H*, is laid upon the top layer of loam, Fig. 73. The irons, *V*, are for the purpose of wedging up and securing the core and cope when finally in place. *H*, bedding firmly on the loam, the spaces between the ribs are filled in with loam bricks, *U′*, and these, with the deep prods cast on the plate, together with the stiff loam daubed between them all, form, when dried, a solid mass which can be turned over with perfect safety for closing the mould. The block, *W*, which gives the metal around the termination of the bottom steam passage of the cylinder, *E*, in Fig. 68, is bedded in, and the whole surface is lastly swept up and finished with fine loam, *SS*, and the whole dried bodily in the stove.

The turning over of a body of bricks, etc., like Fig. 73, is only done in cases where the mass is not excessive. In the example which we have selected there is no difficulty or risk involved in turning over. But in some heavy work it would be necessary to make a reverse mould, and to daub the loam upon that, standing thus in the position in which it is to stand when finished. Also where a reverse mould would not be suitable, the principle adopted in Fig. 72 is often employed, that, namely, of striking one portion of a mould upon another, using a parting ring, *G*, and parting sand.

Loam, like dry sand, must be thoroughly dried, so that no steam issues therefrom. When dried, the mould is blackened with wet blacking, and, as soon as this is

PLAN.

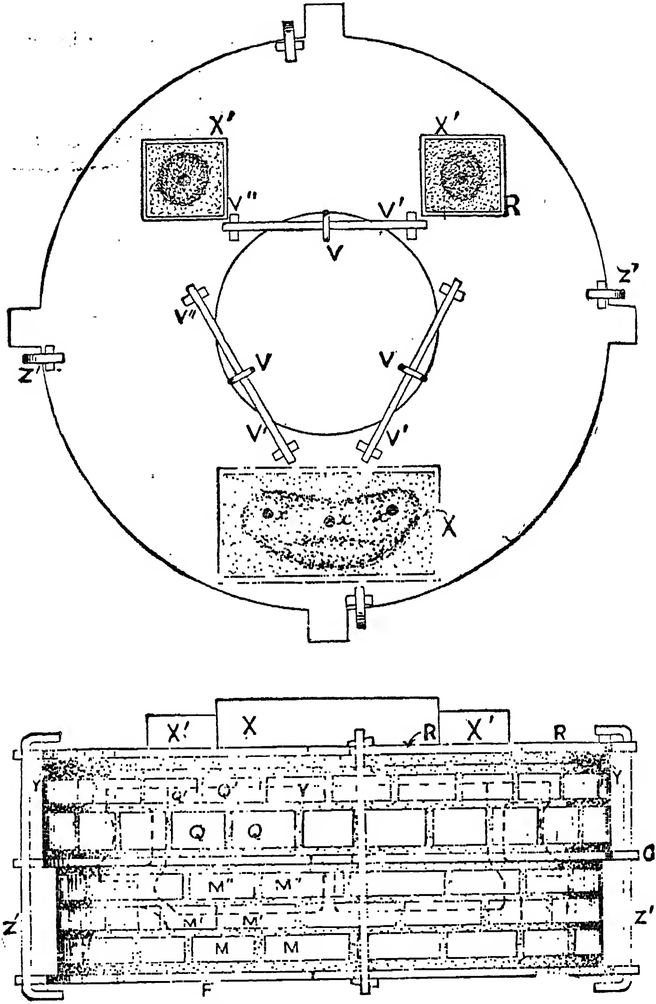


FIG. 74.—LOAM MOULDING.

dry, the mould should be finally closed for casting. The checks K, in Figs. 72, 73, furnish an accurate means of jointing the top and bottom portions of the mould. Holes cut at Y, Fig. 74, enable the moulder to see whether the coincidence of the joints is correct, and if not, where to file away the loam.

Fig. 74 shows the mould closed in readiness to be placed in the casting pit. Similar reference letters will assist in the recognition of parts identical with those in the previous figures, and the outline of the mould is also dotted. The eyes V receive the rods V', which are secured with the wedges V'', thus securing the central core and cope in place. The top and bottom plates, R, F, are clamped together with the clamps Z', Z', which are wedged. Runner pins are inserted at x, to keep the ingates clear during the time of closing, and of placing in the pit. Then the pouring basin, Fig 74, X, and riser cups, X', are made, and all is ready for pouring. In cases where the mould is of considerable size the practice is to fill the central space of a bricked up core, as SS, in Fig. 73, with cinders, previous to casting. If this precaution were not taken, the air filling the vacant space would rush out with explosive violence on the pouring of the metal. The cinders form a natural vent, to the exclusion of excess of air.

Feeding is performed at the riser cups X', and at the pouring basin X. Vents are brought away all over the surface of the cope, and also from the bottom, the latter through diagonal vent pipes.

The mould is sunk into the floor, or pit, and sand rammed

around it, in order to prevent risk of the liquid pressure from forcing out the bricks composing the mould. For large work, therefore, special **pits** are built in the foundry floor. These, when permanent, are built up with cast iron plates, or rings. They are made of depth and diameter most suitable for the special requirements of the foundry.

Loam patterns constitute another type of loam work, having this single point only in common with loam moulds—the material in which they are made. They are employed when the work is of a medium size—too small to be struck upon bricks, yet so large as to involve costly outlay for patterns in wood. They are struck up pretty much like cores on core bars, except that no venting is required, and the surface is protected and rendered hard with a coating of tar. In many cases, however, as when one casting only is required, the core is struck first and vented in the usual way, and then a body of loam, representing the thickness of metal in the casting, is struck thereon, a coat of black wash intervening. The mould is then made and the thickness removed, the black wash acting as a parting, allowing of the ready peeling off of the thickness, and the core is placed in its mould. The boards used for striking are similar to those used for striking cores.

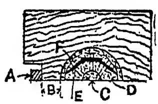


FIG. 75.—STRICKLING.

Loam patterns of irregular outline are worked up with strickles, guidance to which is afforded by means of guide irons, or by striking plates. The principle is simple.

Fig. 75 shows a strickle of half a pipe, working by means of a check against a guide iron, *A*, which is curved longitudinally to correspond with the required outline of the pipe, Fig. 76. The guide iron remains in the same position for both core and pattern, the concentricity of core and pattern being assured by the method of cutting the checks upon each strickle, the distance, *B*, being less in the

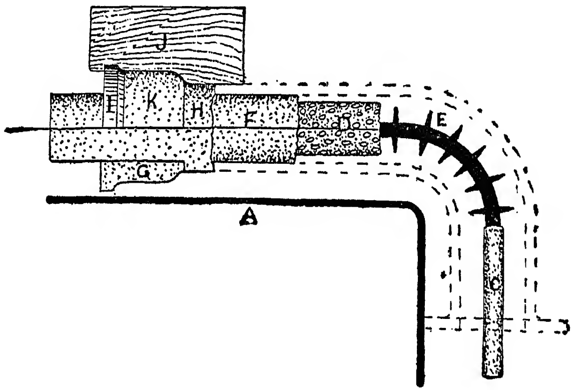


FIG. 76.—LOAM PATTERN.

pattern strickle than in the core strickle by an amount equal to the thickness of metal in the pipe to be cast. In making the core, the vents have to be carried from the outside to the central portion, and away at the ends. Cores are differently made according to their diameters. A small core is stiffened only with a couple of irons. A large one has a grid with prods. In a small one, the central vent is simply cut with a trowel in the joint after each half is dried and turned over, while in a large one

the central vent is formed by daubing the loam over a central body of green sand, first made roughly semi-circular with the hands.

Fig. 76 shows the various stages in making a common **socket bend** in loam. Assume, for the sake of definite dimensions, that it is a 12″ bend with ½″ metal. Then the first thing is to lay down a guide iron, *A*, which may be ½″ away from the outside, and of course 1″ away from the core. Then the core strickle will have a 1″ check, *B*, Fig. 75, and the pattern strickle a ½″ check. Weights will steady the guide iron. First a body of green sand, *C*, is made roughly semi-circular with the hands. Then wet loam is daubed upon this and brought up to within about ½″ of the strickle as shown, Figs. 75, 76, *D*, a cast iron grid, *E*, being bedded in the loam at the same time. While the loam is yet plastic, a number of ⅜″ or ¼″ holes are pierced through it, reaching to the interior. These are the main vents. When this coat of loam has partly set, the finishing fine coat is laid on and swept round with the strickle, as shown at *F*. It is evident that two such halves put together joint to joint and cemented, will form a properly stiffened and vented core.

The enlargement in diameter at the socketed end is usually made by striking up a ring of loam and threading it upon the core, its vents being brought into the main core vents.

The next stage, if one casting only is required, is the striking of the pattern thickness upon the core. Nothing is moved, but the core is coated with black wash, and

the loam struck thereon with the pattern strickle, as at *H*. This also is dried.

The socket is variously made. Sometimes the thickness, forming the socket core, is not put on until after the pipe has been moulded. The socket body is struck and threaded directly on the plain core as at *G*, or a standard wooden or iron socket pattern is slipped over. Sometimes the socket is struck up on its own core, either by means of a guide ring, Fig. 76, *I*, which forms a portion of the pattern, and strickle *J* working thereon transversely, or the two separate diameters *I*, *K* are struck with two separate strickles working from the guide iron, and the curves by which they merge into one another are rubbed by hand with rasps and glass-paper.

When a pattern thickness is struck upon a core as in this case, it is usually necessary to secure the thickness firmly, during moulding and handling about, with flat-headed plasterers' or chaplet nails; without this precaution the thickness is apt to peel off at the black wash joint.

When a pattern is struck, whose diameters vary at every position, no single templet will shape it. Then strickles are made to the extreme diameters, and if the pattern is of awkward shape, strickles for certain intermediate positions, and the loam rubbed between these positions with files or rasps, the eye being the arbiter, with or without the assistance of sectional templets. In a reducing bend three such positions might be taken, one at each end, and one at the centre, and two guide irons would properly be used. The three strickles

resting against the guide irons would give the semicircular outline at each position, and the longitudinal outline of the guide irons would give the curves by which the joint edges of the cores would be imparted, the strickles for these being of a sectional form, giving the edges only.

When the core has been rubbed down to its proper curves, the thickness is variously put on. Thus, strickles may be used at the ends and middle just as in the core. But this leaves the eye to judge of thickness, which in thin castings is too risky. Hence thickness pieces are fitted to the core, being either wood strips, curved or straight, gauged to thickness, or flat-headed nails are driven in by templet. These afford a guide by which the loam is daubed on and strickled off. All these are easily removed after the pattern is moulded and the core is required.

The flanges on loam patterns are usually made in wood, and they rest against the shoulders of the loam which forms the pattern thickness. These shoulders are therefore filed quite square after the thickness has been dried in the stove.

In some loam patterns there is a great deal of this fitting of wooden parts, portions which cannot be made in loam being conveniently made in wood. A little knack and some rough geometry is often essential therefore in this class of work. Centre lines, and lines at right angles, which can only be struck with trammels or compasses, are often wanted, and their accurate laying down is rendered all the more difficult, because many loam patterns are unjointed.

Beyond these special matters, loam patterns have much in common with ordinary patterns. Prints, bosses, brackets, feet, and various other fittings are added thereto, and though loam does not afford such good facilities for fastening these as wood, yet with care on the part of the pattern maker and moulder they can be rendered sufficiently secure; nails, long skewers, and the fitting of shoulders being the safer methods.

CHAPTER IX.

MACHINE MOULDING. PART I.

THE elements of **machine moulding** are to be seen in the use of turn over boards, and in plate moulding, devices which are employed to a greater or less extent in nearly all shops.

Turn over boards, joint boards, bottom boards, as they are variously named, are employed to facilitate the making of the joint faces of moulds. In ordinary work these faces are made by strickling and sleeking down, as noted on p. 36 in connection with Figs. 18-21. But when similar work is often repeated the joint faces are rammed directly upon boards, the contour of whose faces corresponds with that of the joint faces of the sand—flat, if required flat, irregular, sloping, curved, etc., if so required. In the simplest mould, the flask which is to become the drag is laid upon the bottom board over the pattern, rammed, lifted off with the pattern or portion of the pattern belonging thereto enclosed *in situ*, turned over, and the cope rammed upon it. This method is very advantageous in two cases: first, when the pattern is so flimsy that it would probably become rammed out of

truth, or could only be kept with difficulty from winding during ramming; and second, when the parting joints are so uneven, unsymmetrical, curved, sloping, and irregular, that to cut and sleek them with the trowel at each time of moulding would entail much loss of time.

Plate moulding is an advance upon this practice. With the use of turn-over boards, the cope and drag are rammed joint to joint in the positions which they are finally to occupy at the time of casting. But in plate moulding the joint faces are not brought together at all until the time of final closing. The pattern is divided into two portions, one portion being upon one side of a plate of wood or metal, the supplementary portion being upon the opposite side. Or in many cases distinct plates are employed, each carrying that portion of the pattern which is the supplement of the portion on the other plate. Cope and drag being rammed, each on its respective side of the plate, or on its separate plate, form when brought together a complete mould, corresponding at the joints. Thus, taking an example, the trolly wheel shown in Fig. 18, p. 35, would, if moulded on a plate, be made as

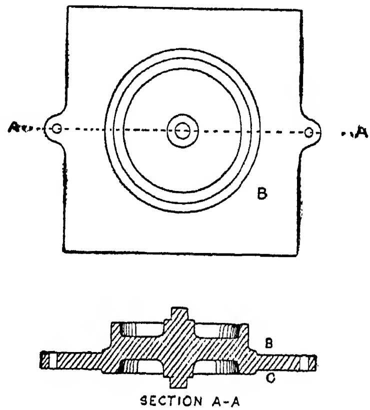


FIG. 77.—PLATE MOULDING—TROLLY WHEEL.

in Fig. 77. It is clear that the portion of the wheel on the face *B* of the plate is supplementary to that on face *C*. The faces *B* and *C* form the joint faces of the drag and cope. Patterns like these are arranged singly or in series on plates, according to size and quantity required. A pattern of large size will occupy a plate to itself; several small patterns, alike or dissimilar in character, may be arranged on one plate, and poured from a central ingate and spray of runners.

Now the use of a **moulding machine** consists mainly in this, that in place of the clumsy and often inaccurate separation of the pattern plates from the flasks by hand, there is substituted the steady, equal, and perfect separation by mechanism. Some of the more recent machines include much more than this, as the ramming or pressing of the sand around the patterns, the use of stripping plates, that is, plates through which the patterns are drawn, the plates sustaining the sand and preventing broken edges; but such elaboration is not essential to machine moulding, though often convenient and advantageous. The subject of moulding by machines is one of much interest, but the space at my disposal forbids anything beyond an illustration and detailed description of one in particular, and a summary of the essential construction of several distinct types.

Messrs. Woolnough and Dehne's patent moulding machine, manufactured by Messrs. Samuelson and Co., Ltd., Britannia Works, Banbury, is illustrated in Figs. 78-81. Fig. 78 is a perspective view of the machine, Fig. 79 a sectional elevation of one of the standards, Fig. 80 a

horizontal section through the standard on line *A-B*, and Fig. 81 a section through the cap at the top of the pillars. A base plate, Fig. 78, carries a couple of pillars,

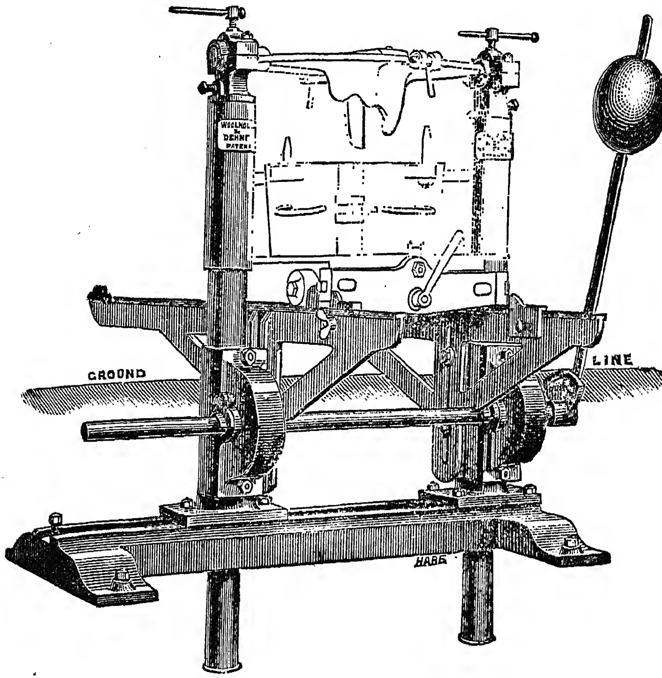
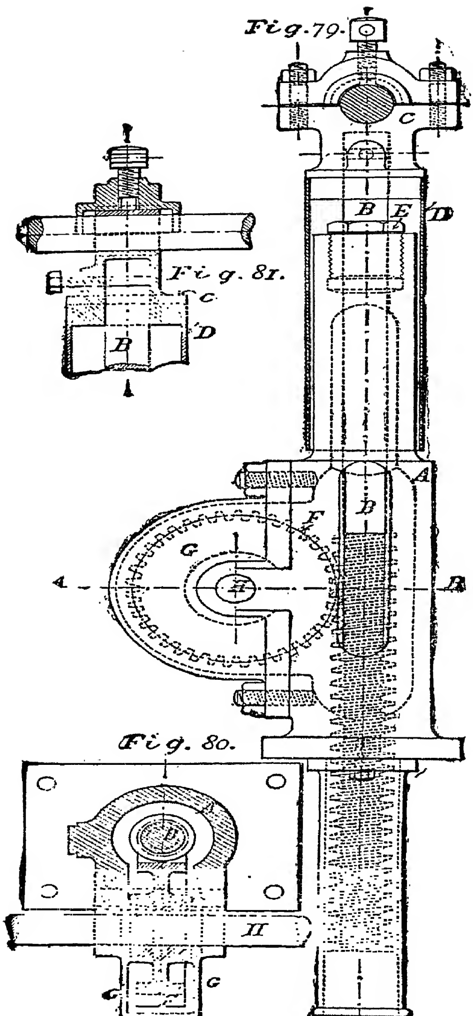


FIG. 78.—WOOLNOUGH AND DEHNE'S MOULDING MACHINE.

one of which, that to the right, is permanently fixed, the other, that to the left, is capable of horizontal movement, rendering the machine adjustable to the width of any

pattern plates within its range. The pillars *A*, Figs. 79, 80, 81, are hollow, enclosing spindles *B*, to which vertical movement can be imparted by means of the weighted lever handle seen in Fig. 78. The lever actuates the horizontal shaft *H*, Figs. 79, 80, upon which are keyed two worm wheels *F*, enclosed in the semi-circular casings *G*. The shaft and casings are seen at the front in Fig. 78. The worm wheels engage with screws cut on the vertical spindles *B*, Figs. 79, 80, 81, and so raise and lower the pattern plate, which has its bearings, *c*, in the upper ends of the spindles, and which can be turned over in its bearings. Two triangular plates furnished with slots and bolts for vertical adjustment slide in faces upon the pillars, Fig. 78, and their upper edges form the tracks for the wheels of the plate, upon which the moulding flask is supported. The provision for vertical adjustment permits of the employment of flasks of various depths.

The method of moulding is as follows:—That face of the pattern plate from which the impression is to be immediately taken, whether for cope or drag, is turned uppermost, and the appropriate flask placed thereon and clamped or screwed. The sand is then rammed in by hand, and scraped level. The flask and plate are turned bodily over and lowered, until the back of the flask rests upon the table beneath. The pattern plate is then pinched in its bearings with the set screws seen at the tops of the pillars, and lifted clear of the flask by the lever handle, in which position it is shown in Fig. 78. A very slight amount of rapping is imparted to the pattern plate



WOOLNOUGH AND DEHNE'S MOULDING MACHINE.
SECTIONAL VIEWS.

in the act of withdrawal. When the mould is blacked the pattern may be returned temporarily in order to press the blackening down, thus saving the trouble and risk of sleeking. These machines, in one size, will take flasks measuring $27\frac{1}{2}'' \times 21\frac{1}{2}''$, in another, $39'' \times 21\frac{1}{2}''$, with a perpendicular lift of $8\frac{1}{2}''$. The table, flask, and pattern plate are unshaded in Fig. 78.

The sleeve *D*, Figs. 79, 80, is simply for the purpose of protecting the vertical spindles from access of dust, and a screw gland, *E*, similarly protects the worm and worm wheel.

The introduction of this machine will give a fair idea to the student of the general principle of construction adopted; while the following summaries will assist the practical man to form some idea of the efforts that have been made to devise new and improved forms.

Georg Sebold and Friedrich Neff, Germany. Wirth's Patent, 1879. No. 3,227.

A very ingenious machine, the two essential points of which are the production of an automatic and strictly equable pressure of sand over patterns of irregular configuration, and the automatic regulation of the precise amount of pressure required in any particular case. To obtain the first, melted gutta percha is ran all over the pattern or patterns to form a reverse impression, which impression is then attached to the pressing plate, and so, following the pattern contour, imparts a pressure more uniform than can possibly be imparted by a flat plate operating on patterns of irregular outline.

The second point, that of imparting a measured amount of pressure adapted to each individual job, is accomplished by allowing the table which supports the moulding box and its carriage to rest by four vertical pins upon the short arms of four weighted levers, the radii of whose weights is capable of adjustment on a series of notches, for the production of greater or less effect. When therefore pressure is exerted on the sand in the moulding box by the pressing plate, that pressure cannot exceed the amount necessary to just overcome the resistance of the loaded levers. The most suitable amount of resistance can easily be gauged by experience for each particular job, and the weights adjusted accordingly. The table is elevated by means of a winch handle and gearing.

The same inventors took out letters patent for improvements in moulding machines in 1882, No. 855, but the specification, containing thirty-seven figures, is too lengthy for summary.

Messrs. Wren and Hopkinson, Manchester, 1880.
No. 5,344.

This relates to improvements on the machine just described. The moulding flask is brought underneath the presser upon a travelling carriage running on rails, the rails being prolonged beyond the machine upon brackets bolted to the side cheeks or frames. The table which sustains the carriage and flask immediately underneath the presser at the time of running on of the carriage, has its rails at

the same level as the rails upon the brackets. It is raised for the operation of pressing by means of a train of gearing arranged on three parallel shafts, a pair of connecting rods pivoted eccentrically on the third motion shaft imparting an upward or downward movement to the carriage, which slides within suitable guides.

The flask is not rammed upon this carriage, but upon a turn-over, or reversing table above, provided with suitable cottar pins. Upon this the flask is placed, over the pattern, and cottared. This table slides in vertical guides, its motion being arrested at a definite stage, with the pressing plate placed above it. This plate is made to tilt at an angle, and is so connected with a sand box, that at the time of tilting, the mouth of the sand box may discharge its contents into the moulding flask below, which at that time is surrounded with a filling frame. When the requisite quantity of sand has been raked in, the pressing plate is turned up and locked in the horizontal position, the train of gearing beneath the carriage is brought into operation, and the requisite pressure exerted, between the carriage beneath and the presser above the carriage, the latter moving upwards and thrusting the moulding table and flask against the presser. The sand being thus consolidated, the gearing is reversed, the carriage and flask are drawn down, the sand is scraped level with the edge of the flask, the moulding table is turned over, and the flask deposited on the carriage and ran away upon the rails.

There are also several points of detail which we have omitted for the sake of brevity, including the formation

of a special jagged form of runner and a separate table for the registering and cottaring together of the cope and drag in readiness for casting.

Peter Gallas and Heinrich Aufderheide, Germany. Wirth's Patent, 1880. No. 5,469.

A machine of a very automatic character, and somewhat complicated, though apparently quite efficient. The moulding box is brought by a carriage over the pattern plate and fastened with clips. A pressing frame surmounted by a sand box, also running on wheels, is brought over the moulding box. The necessary facing sand is sieved over, and the sand for box filling is strewn over this. Then by an ingenious mechanism, consisting essentially of toothed spiral cams, the pattern plate is thrust upwards against the pressing frame and plate above. The spiral cams are so arranged that the vertical motion, rapid at first, is gradually lessened in speed, with increase of force. A hand wheel operates the cams, and these in turn act upon racks. After ramming, the carriage is released, the sand in the moulding box strickled level with the back with a steel knife, the box turned over, the carriage brought back to support it, and the box removed downwards from the pattern plate.

Among other points worthy of note are these, that the weight of the pressing table and carriage are counterbalanced, that the separation of the pattern plate and mould is assisted by the circular movement of a bar of steel of polyhedral section, by whose rotation a slight up-

and-down movement is imparted to the pattern plate, producing a result akin to rapping, that a rocking motion is imparted to the sieve in the sand box, and there is the proposal to use the electric current to repel the moulding box and pattern plate. There is also a subsidiary piece of apparatus for jointing the halves of the mould.

Samuel Siddaway, West Bromwich, 1884. No. 10,189.

A machine which has the merit of simplicity, and is therefore well adapted for the miscellaneous and general work of a shop. The pattern plate is carried on the end of a strong piston, moving in a vertical guide, and actuated by a pair of hand levers of ample length operating a crank shaft and links. The sand box and moulding flask cover and enclose the pattern plate, and the necessary resistance to the upward pressure of the pattern plate is afforded by a swinging cover or binder, which is clamped over the flask with screw bolts during the time of pressure, and swung aside when the mould is made. The whole machine is carried on wheels for convenience of portability.

Edward Buckley, Stalybridge, 1885. No. 2,777.

A table runs to and fro upon rails between side frames, and carries the moulding flask. The range of travel of the table is such that the sand is filled by hand when quite clear of the body of the machine, and is then ran underneath the presser for consolidation. The mechanism by

which it is run underneath consists of a tappet actuated by a hand lever, operating against a stud on a weighted rocking lever. As the tappet is thrown over to one side or the other of the stud, the table is pushed into the position for filling, and the position for ramming respectively, and is kept by the weight and pressure of the rocking lever in either position. Spring buffers at each end of the table prevent violent shock at the extreme limits of its travel. The presser is operated by the same lever as the table, the pressing mechanism consisting of a spiral cam, which on being pulled down with the lever, acts upon a small roller having bearings in a slide moving vertically in guides, to which slide the pressing plate is attached. On the release of the lever, the plate is lifted by a spring or other suitable device.

A modification of this invention consists in a reversal of the process, the presser plate being made fixed, arranging the scroll, cam, etc., so as to lift the rails together with the table and moulding plate bodily up to the presser.

Fred Ryland, County of Stafford, 1885. No. 3,319.

This relates only to one section of the mechanism employed in moulding. A moulding table is constructed to run upon rollers around a circular roller path. The top of the table is provided with four projecting brackets, with provision for receiving four moulding flasks. The advantage is, that a succession of moulds can be operated at once, one flask being filled while the next is being consolidated by hydraulic or other pressure.

Arthur Rice, New Albany, Indiana, 1885. No. 8,530.

This is a machine specially designed for the moulding of work whose sides are vertical, and in which therefore a clean draw is facilitated by the use of stripping plates. Spur wheels, rings, bushes, are the class of work for which the provisions of this machine are admirably adapted.

The pattern is fixed to a metal plate, and its outline or perimeter is encircled with a templet or stripping plate. If hollow, a similar stripping plate is fitted to the interior. The pattern plate is fixed to the framework of the machine with the movable templets in place, and is encircled and covered with a moulding box containing sand ready to receive pressure. This pressure is imparted through a belt pulley to a shaft on which are keyed cams, which as they turn with their shaft, operate two yokes or bridles attached to vertical rods connected to a plate, and this as it thus rises or falls operates both the internal and the external templets or stripping plates. The flask with its sand is pulled down upon the pattern by means of disc cranks set outside the framing of the machine, and upon the same shaft as the cams,—connecting rods establishing communication between the wrist pins and the binder plate above the flask. The arrangement of these cams and cranks is such, that after ramming, the stripping plates are withdrawn from the pattern simultaneously with the delivery of the sand.

Matthew Robert Moore, Indianopolis, Indiana, 1884. No. 10,436.

This is substantially an invention to produce even or uniform ramming of moulds of irregular form by means of fluid pressure. The patterns, laid upon their bottom board, are enclosed in a flask. The flask is temporarily locked with suitable links to a piston or platen above. The latter has a diaphragm of india rubber upon its under face. This is filled under pressure from a hose, with any suitable fluid, pressure being regulated with a stop cock. This diaphragm operates a bundle of rods of wood occupying the mould area and pressing upon it endways, the bundle being held together with an encircling ring, having sufficient friction to lift the rods bodily while yet allowing them freedom of movement in relation to each other endwise. The inventor claims that by this arrangement "the flexible diaphragm will so distribute the pressure that the thinner parts of the sand will only yield until they reach that degree of compactness which will enable them to resist the pressure applied, when they will cease to be further compressed, while the thicker portions will continue to yield until every part of the mould has attained a uniform degree of compactness due to the pressure applied." There are also modifications of this patent.

Matthew Robert Moore, 1885. No. 14,385.

A machine in which pneumatic pressure is employed for the consolidation of the moulds, and in which both

cope and drag are rammed at once, and the sections of the patterns corresponding with cope and drag, withdrawn simultaneously. The machine may therefore be properly denominated a duplex pneumatic machine. The air bags are composed of separate diaphragms constructed in two or more horizontal layers of hemp, linen, or cotton, vulcanized. There is a stop cock connected with each separate diaphragm by which the pressure can be increased or diminished in any one, independently of the others, the whole being connected with a flexible india rubber hose provided with a main two-way valve. The patterns are contained in a pattern box, which is open top and bottom, except for two stripping plates fastened to top and bottom faces through which the vertical portions of the patterns project. A shaft turned with a winch handle and furnished with cam-like levers, presses the patterns outward, so that they may receive the pneumatic pressure of the sand, and withdraws them simultaneously afterwards.

Matthew Robert Moore, 1886. No. 9,663.

This is an invention designed to obviate the defects found to be inherent in the machine of No. 10,436. Here two pattern boxes and sets of mechanism are employed, and arranged in such a manner that the boxes can be raised and lowered alternately and turned round horizontally, and one box with its parts balances the other. The pressing apparatus consists of a series of india rubber diaphragms fixed upon an upper plate set

in the required vertical positions by means of screwed rods and nuts, and filled with air from a hose pipe. To one side of the base plate of the machine is attached a rigid pillar, upon which pivots a sleeve carrying rigid arms actuated by levers, in such a way that the pattern boxes can be alternately raised and lowered, always however remaining horizontal. They are thus swung, each in turn, first under a sand hopper from which they receive a supply of sand, and then under the pressure platen. When in the latter position air is admitted between a movable cap and a rigid piston in the base of the machine, and the upward movement of the cap forces the flask with its contained sand against the platen, consolidating the sand. While this is going on, an attendant is getting ready the other pattern box. Both stripping plates and divided patterns can be used, if required, with this machine, and various links and slides are employed for operating the patterns.

George Guntz, Wilkes Barre, Pennsylvania, 1887.
No. 4,839.

This is a most elaborate machine, designed primarily for a special purpose, namely, the moulding of car wheels, which, as my readers are aware, are in America always made of judiciously selected mixtures of cast iron, and chilled on the tread. It consists essentially of a revolving table, driven from belt pulleys and pierced with half-a-dozen holes for the reception of cast iron patterns. The table is carried round by means of a

circular toothed rack, and there is a cam and sliding clutch, and spring latch arrangement by which its motion is automatically rendered intermittent, ceasing when a pattern is brought under the pressing apparatus, starting when the precise series of operations involved in ramming and delivery are concluded. The pressing apparatus consists of two hydrostatic cylinders, one above, one below, whose rams are operated simultaneously to, or from the pattern, by valves opened and closed automatically by means of a cam. The pressing plate is secured permanently to the upper ram, moving with it. The contour of this plate is of the same dished form as that of the back of the wheel pattern. There is a sand reservoir supported above the table, to one side of the pressing apparatus. This is made to register with the moulding boxes, and fills them in turn from sand valves as they are brought underneath it on their way to the presser. The pattern is sustained at its proper height in its hole by means of weighted levers. A hoop surrounds the pressing plate and prevents the escape of sand during the act of pressure. After compression, the pressing plate, and immediately after, the hoop, are lifted clear of the mould; the operation of the cam sets the table revolving, carrying the flask round one-sixth of a circle, and the superfluous sand is scraped off the flask face with a steel knife. As the table revolves, the loaded levers by whose operation the pattern was sustained, come into contact with inclined segments of circles bolted to the foundation of the machine. These throw the levers into the horizontal position, allowing the pattern to descend

below the level of the table, leaving the mould ready for removal to the casting pit.

This is but the baldest summary of the method of action of a machine which is so beautifully designed for its own class of work as to be well worthy of a more extended study on the part of specialists in this line.

Harris Tabor, Liberty Street, New York, 1887.
No. 9,129.

An American invention, in which a cylinder with a piston, and entry and discharge pipes, and actuated by steam, air, gas, or water, is utilized as the pressing apparatus. This cylinder is located at the upper part of a standard or framing, its precise vertical position being adjustable for moulds of different depths. To the piston rod, projecting downwards, is attached the plate, to which, in one form of the invention, the pattern is attached; the pattern passing through a stripping plate. The moulding flask is carried on a moulding table beneath, lugs on the table being arrested and held at a certain position on wings or projections coming out from two vertical rods sliding in the main framings, to the upper ends of which rods the pressing cylinder is attached. The moulding flask is carried on a table which is run underneath the presser after the sand has been filled in. The lugs on the side of the moulding table then rest on the wings projecting from the vertical tension rods, and afford the necessary resistance to the pressure imparted from the cylinder above. The pattern is thus pressed *into the sand* and withdrawn through the strip-

ping plate. Since pressing the pattern into the sand is bad practice, we note with satisfaction that the patentee includes the alternative and correct practice of pressing the sand over the pattern, and withdrawing the pattern downwards from the mould through the stripping plate, the same mechanism being employed.

CHAPTER X.

MACHINE MOULDING. PART II.

Wheel moulding machines, though extensively used, have not yet found their way into all our shops, so that there are still many moulders and pattern makers who have had no experience whatever of them. The writer is aware of the existence of about six or seven different types—Jackson's, Scott's, Whittaker's, Buckley and Taylor's, Hey's, and Simpson's. The machine of Messrs. Buckley and Taylor, of Oldham, is selected, by the permission of the manufacturers, for illustration in this volume. It is substantial, stable, accurate, and cannot easily get out of order by wear, all points of the first importance in machines of this class. Before discussing the actual moulding of wheels, I will describe the construction of the main framework of the machine itself.

The illustrations, Figs. 82 (see frontispiece), 83, 84, represent a *table machine*, that is, one in which the moulding flasks are set and rammed on a table. In the *floor machines* the lower portion of the work is rammed in the foundry floor, and a flask is employed to form the cope mould only. The first class of machines are

used for wheels of small and of moderate dimensions,

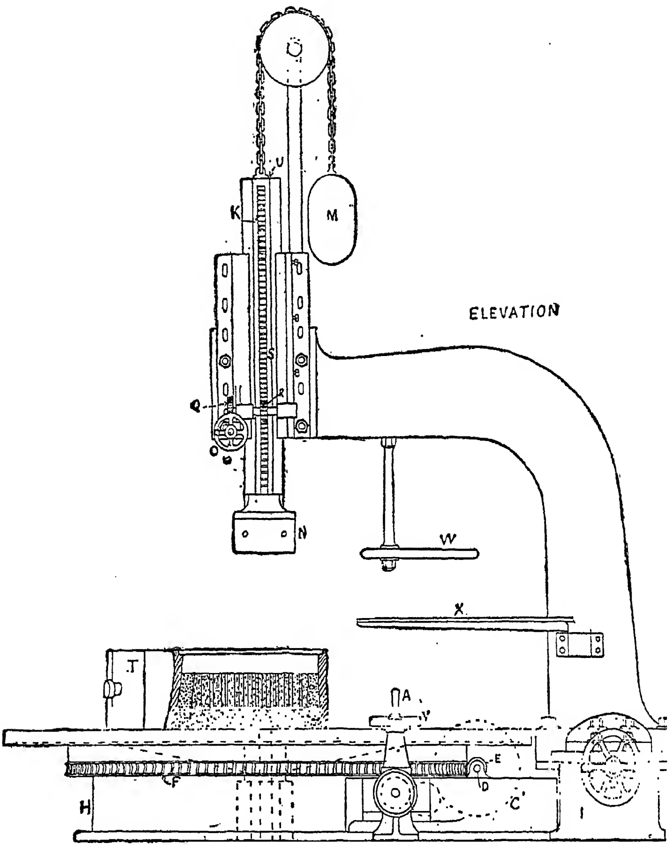


FIG. 83.—WHEEL MOULDING MACHINE.

the second class for those of large diameter. The table machines are entirely self-contained, but all the

upper portions of the floor machines are portable, that is, all the essential dividing apparatus and carrier arms are, when required for use, set down over a central pillar or base sunk permanently and levelled in the foundry floor. This machine of Messrs. Buckley and Taylor is made capable of employment in each capacity, the upper portion being removable, and the base, with the dividing apparatus, being adapted to fit into a massive bed in the floor, while a radial arm, made to slide in vee'd guides screwed upon the bed, is substituted for the arched arm. This radial arm carries at one end the vertical slides for the tooth block, and the radius of the wheel to be moulded is only limited by the length of the arm. Wheels up to 25 feet are moulded in the floor machine.

Fig. 82 (see frontispiece) is a perspective view of the machine,—upon which a bevel wheel is being moulded. Figs. 83, 84, annexed, are an elevation and plan of the same. In these, *H* is a strong foundation against which the bed *I* is bolted. The table fits by means of a stout turned pin into the boss of the foundation plate *H*. This table carries the moulding flask *T*, having upon it a sectional portion of a spur wheel mould, and is revolved by means of the dividing wheel *F*, and tangent screw *E*. The bed *I* carries the arched arm *J*, at whose extremity moves the vertical slide *K*, to which the tooth block is bolted.

The essential mechanism by which the dividing out of the wheel teeth is effected is as follows. The dividing wheel *F* is attached to the under side of the table. Into

this gears the tangent screw *E*. This is actuated by the

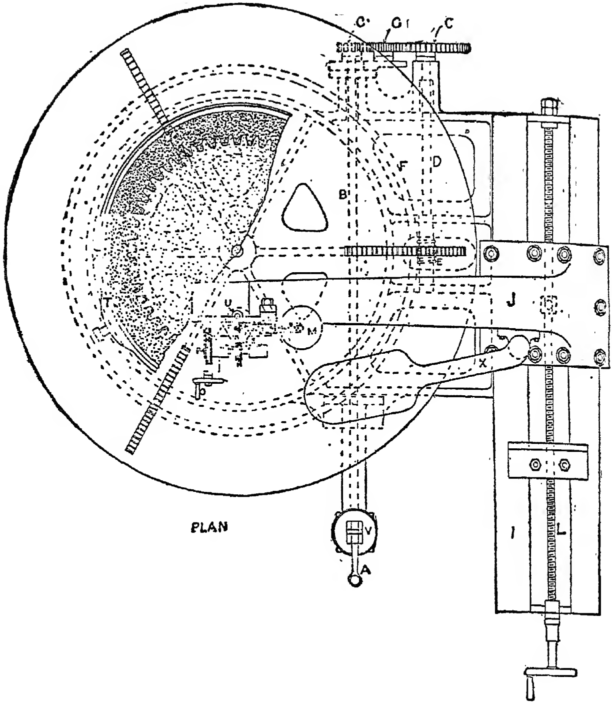


FIG. 84.—WHEEL MOULDING MACHINE.

handle *A* turning around on a notched division plate *V*. The short hollow pillar beneath encloses a pair of small

mitre wheels, through which the motion of the handle *A* is communicated to the shaft *B*, at whose opposite end the first change wheel *C* is placed. This gears through the idle wheel *G* with the change wheel *C′* upon the tangent screw shaft *D*. Any wheels of the set usually supplied with these machines are interchangeable at *C*, *C′* and *G*, a slotted quadrant plate, together with the idle wheel *G* furnishing the means of adjustment for centres. Of course the idle wheel counts for nothing in the calculation of the train.

Suppose the tooth block to be set at the correct radius for any given wheel to be moulded, by the sliding along and pinching of the arm *J*, on the bed *I*. It is evident that a single turn of the single threaded worm *E* would pass the dividing wheel *F* a distance equal to one tooth. Hence, having wheels of equal diameter at *C* and *C′*, and giving one turn to the handle *A*, a wheel would be moulded on the table having precisely the same number of teeth as the dividing wheel. But by employing unequal change wheels to connect the handle shaft *B*, and the worm shaft *D*, and by doubling or trebling or quadrupling the number of turns of the handle, or by giving to the handle some definite fractional portion of a turn only, we have, as in the screw-cutting lathe, a means for establishing almost any number of proportional relationships between the number of teeth in the dividing wheel *F* and the wheel to be moulded. Hence the rule, "As the number of teeth in the dividing wheel is to the number of teeth in the wheel required to be moulded, so is the number of teeth in the wheel on the handle shaft

to the number of teeth in the wheel required on the worm shaft."

Thus: suppose a wheel of 100 teeth has to be moulded. The dividing wheel F has usually 180 teeth. Put, say, a 90 toothed wheel on the handle shaft. Then:—180 : 100 : 90 :: 50. A wheel of 50 teeth would therefore be put on the worm shaft D, and *one* turn given to the handle shaft B. But supposing we have not got a wheel of 50 teeth, we can multiply 50 by 2 = 100, and put a wheel of 100 teeth on the worm shaft. But then we must give *two* turns to the handle. For in any case, if we multiply the quotient which gives the number of teeth on a change wheel on the worm shaft, we must also multiply the number of turns of handle, or if we halve the number of teeth, we must halve the number of turns given to the handle.

If we are doubtful of the wheels, they may be proved thus. Divide the number of teeth in the wheel on the handle shaft by the number of teeth in the wheel on the worm shaft, multiply the quotient by the number of turns given to the handle. The product will be equal to the quotient of the number of teeth in the dividing wheel divided by the number of teeth in the wheel to be moulded. Thus in our first example:—

$$\frac{\text{Handle shaft} \quad . \ . \ . \quad 90}{\text{Worm shaft} \quad . \ . \ . \ . \quad 50} = 1{\cdot}8 \times 1 \text{ turn} = 1{\cdot}8.$$

$$\frac{\text{Dividing wheel} \quad . \ . \ . \quad 180}{\text{Wheel to be moulded} \quad 100} = 1{\cdot}8$$

The mechanism for actuating the **tooth block** is as follows:—The *radius* of the block is adjusted by means of the arched arm *J*, which travels upon the bed *I* to or from the centre of the table. This is adjusted with the screw *L*, and clamped by the pinching screws in its foot in its required position, remaining immovable during the whole period of the ramming of the wheel teeth. The vertical slide *K* is carried in vee'd guides, which have provision for the taking up of wear. It is actuated by the small hand wheel *O* turning the worm *P*, which revolves the worm wheel *Q*, upon whose spindle is the spur pinion *R*, gearing with the rack *S* attached to the vertical slide *K*. The slide is counterbalanced by the weight *M*. The vertical movement of the slide is checked at the proper position by means of the adjustable stop *U*, so that there is no risk of the tooth block being thrust down too hard upon the sand bed. The lower portion of the slide receives the carrier *N* to which the tooth block is attached.

The essential portions of the machine are therefore the firm base *H*, the revolving table carrying the flask *T*, with the dividing apparatus, the arm *J* moving radially in reference to the table, and the provisions for the vertical movement of the tooth block. The tables *W*, *X*, are simply convenient attachments for the reception of the moulder's small tools. We are now in a position to take up the details of the actual moulding of toothed wheels.

Spur wheels are moulded very simply. The teeth are formed with a block, and the arms by means of cores.

The block, Fig. 85, has two teeth only, and the inter-tooth space alone is used in the formation of the mould. A bed is first struck, Fig. 86, with a board attached to the striking bar *A*, the depth *B* being equal to the depth of the face of the wheel, the bottom edge *C* striking the bed, the top edge *D* the top or joint face. The striking bar *A* in Fig. 86 is a bar turned to fit into the bored hole in the centre boss of the table in Figs. 83, 84. The *strap* *E* is bored to fit over this bar, and its shoulder *F* is cut to a definite distance from the centre of the bar, so that the radius of any striking board is less than the radius of the wheel by the distance *G*. The central bar or "post" *A* is removable at pleasure. Its purpose is, first, the carrying of the strap or bracket *E*, and second, it is the part from which the radius of the tooth block is measured.

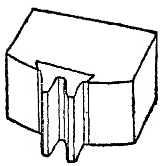


FIG. 85.—TOOTH BLOCK.

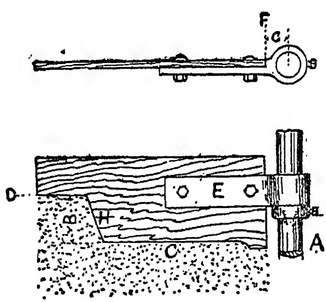


FIG. 86.—STRIKING BOARD.

The vents from the bed are carried down to a coke bed if the wheel is moulded in the floor, to the bottom of a flask, if in a flask. The tooth block is screwed to the carrier, set to the correct radius, either by means of a strip or gauge cut to reach the precise distance from the post

of the machine to some portion of the block,—either root or point, and the machine is clamped to preserve that distance constant. The length of the gauge will be equal to the radius of the root or point, as the case may

Fig. 87.—Radius Gauge.

be, minus the radius of the post. Or a gauge, Fig. 87, may be cut to fit partly round the post *A* in Fig. 86, and the radius be marked upon that to root or point. The radius once obtained, and the arm clamped, the gauge strip is no longer required. The block is lowered until its lower face bears upon the sand bed, and then the stop *U*, Fig. 83, is clamped, and all is in readiness for the ramming of the teeth.

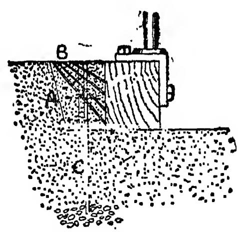


Fig. 88.—Ramming of Tooth Block.

It will be noticed that the edge *H* of the board in Fig. 86 is chamfered or bevelled. This is not always done, but it is a good plan, as is apparent by the sectional view in Fig. 88, where the tooth block is seen in its exact relationship to the circular wall of sand *A*, within which it is rammed up. Space is left between the points of the teeth, and the outer roughly-struck wall of sand, in order to give a narrow zone for ramming facing and strong sands into, and the wall is made sloping, because

it is easier to sweep up than a perpendicular wall, from which the sand would tumble down.

Facing sand is thrown into the space between the wall *A* and the teeth, and strengthened with nails (dotted). The sand is rammed between the teeth with a small pegging rammer, being, for these small teeth, only a rod of round iron flattened and narrowed at one end. When the inter-tooth space is filled, the sand is levelled over with a flat rammer, scraped and sleeked with the trowel, and vented diagonally, the vents *B* passing into a main vent *C*, either going down to a coke bed, or coming out in the joint of the flask. Only the inter-tooth space gives the tooth shape, and one tooth space only is rammed at a time. I have sometimes seen more than two teeth used, but there is no advantage whatever in their employment, and the difficulty of making the block is increased. Only in the case of mortice wheel blocks carrying prints is there any advantage in adopting four or five instead of two teeth. The hinder part and the ends of the block are slightly rapped with the hammer before the withdrawal of the teeth; but there is no rapping in the sense in which it is employed with ordinary patterns. The pattern is simply started, nothing more, and the block lifted without any sensible lateral play. There is, or should be, no taper in the tooth space, and the sand would therefore become torn up on the withdrawal of the block but for the fact that it is held down by a finger-bit cut to the shape of the inter-tooth space, upon which the moulder presses the two forefingers of his left hand while elevating the slide with his right

Having lifted the block clear of the mould, the requisite number of turns is given to the handle shaft, and the block thereby carried round a distance equal to the pitch. The slide is then lowered, bringing the block into a suitable position for ramming the succeeding tooth, the process for each tooth being simply a repetition of the first. In order that the outside faces of the teeth on being lowered shall not scrape or push aside the sand already rammed, taper is given to the outside faces, so that the outer edges of the block do not come into actual contact with the sand at all, or at least, only when finally in place, the top edge may just coincide. Also, to prevent the sand from tumbling down on the side opposite to that which is already rammed, a block of wood is laid against the tooth block to sustain the sand in that direction during ramming.

The cores for the arms are made in dried sand, and set in place without prints, by measurement alone. The arms of spur wheels are usually **H** shaped in section, partly because of their superior strength, but chiefly because they are rather easier to make than arms of **+** section or **⊥** section. A core of this kind is seen in plan, Fig. 89, a section in Fig. 90, and its grid in Fig. 91. The core is rammed upon the grid, the central part being composed of cinders, the main vent being brought off at the top, *A*, into which all the smaller diagonal vents are carried, as well as the vents from the cinders.

Wheels having arms of **+** or **⊥** shape can be also made in cores, though not so readily as the **H** section. The difficulty is that these cores may have to abut and

joint against each other, while with the H form they are kept asunder by an amount equal to the thickness of the vertical arm. The joints must abut when the edges of the arm are rounding, as in Fig. 92; also, while the

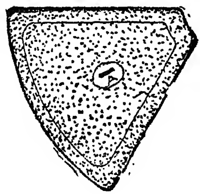


FIG. 89.—ARM CORE.

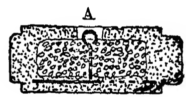


FIG. 90.—SECTION OF CORE.

top and bottom faces of the cores for H arms always lie in the same plane as the faces of the wheel teeth, those of the other sections usually do not. A special bed and cope have to be struck, and cores dished to correspond, when the arms are dished as in Fig. 93.

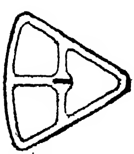


FIG. 91.—GRID FOR ARM CORE.

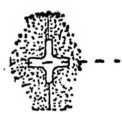


FIG. 92. ABUTTING CORES.

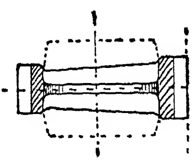


FIG. 93.—DISHED ARM.

This brings me to remark, that those wheels whose copes are not plain, are struck in two ways, either **directly**, or upon a **reverse mould**. Fig. 94 shows the method of making a reverse mould for a *bevel wheel*, where *A*

is the board, swept round over a hard-rammed bed of sand *B*, the edge *C* coincides with the top edges of the arms, and therefore with the top face of the cores of

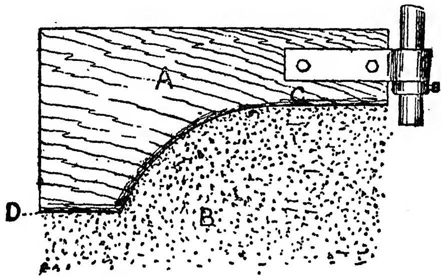


FIG. 94.—BOARD FOR REVERSE MOULD.

the bevel wheel, and *D* is the joint face dividing the cope from the drag. Upon this bed, the board being removed, the cope is rammed, parting sand intervening,—being liftered and vented precisely as though it were being

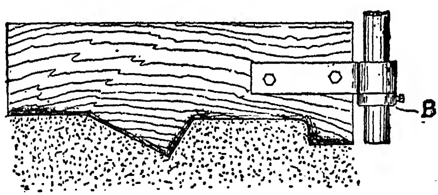


FIG. 95.—BOARD FOR STRIKING BED.

rammed upon a pattern. This is then taken away, and after the wheel is moulded and cored up, is returned finally into position.

On the removal of the cope, the sand which formed the reverse mould is dug out, and the board for striking the lower face, and the circle corresponding with the tooth points, is attached to the strap and slipped over the bar, Fig. 95, the edge *A* coinciding with the joint face *D* already struck by the previous board, and the bottom sand swept out. The tooth block is then attached to the carrier and set in position, and the ramming, nailing, and venting proceeds generally on the same methods as those pursued in the case of spur wheels, modified only by the

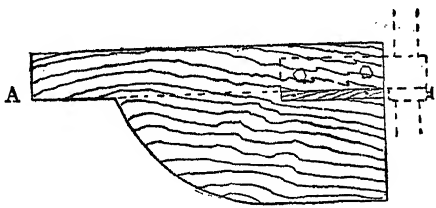


FIG. 96.—BOARD FOR STRIKING COPE DIRECT.

bevel form. The alternative method of making the cope by a **direct** process is as follows:—The centre pillar always has a movable collar fitting over it, seen in Fig. 95; this collar is set and pinched in such a position that its top face coincides exactly with the top or joint edge of the flask on the table, as checked with a straight edge. The boards, both for striking the cope and the drag, have strips nailed upon them, sometimes one strip only, sometimes two, the distance between the strips in the latter case being equal to the width of the strap, and the inner face of one strip coinciding with the joint edge of the

mould. Figs. 96, 97, show the two boards, Fig. 96 striking the cope direct. It is clear that the collar remaining in the same position on the post, the joint faces, *A*, *A*, of cope and drag will coincide, if the fittings of the flasks and post are perfect. In work of this kind the flasks have properly to be turned and checked on their joint faces, specially for wheel work, but in the method first described any flasks can be used, and the wheel can be moulded in the floor just as well as on a table. When wheels are moulded in the floor the first method is the

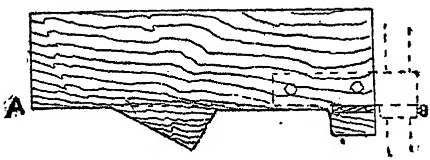


FIG. 97.—BOARD FOR STRIKING BED.

only one which can be adopted without risk of a crush or of finning occurring. The cope being rammed in place, must, when the mould is closed for casting, make a perfect joint with the mould in the floor.

A few notes on wheel machines of other types than the one illustrated must close this chapter.

Scott's machine is of the floor type. A cast iron base or "centre" is sunk and levelled in the floor, and over this fits a pillar, having a head at its upper end bored to turn freely thereon, on which slides the main arm of the machine, capable of radial adjustment. A bracket forms an integral portion of the head, carrying in bearings

a tangent wheel gearing into a worm wheel keyed on the top of the main pillar; a quadrant plate and change wheels establish a connection between the division plate and handle shaft and the tangent wheel. One end of the arm carries the vertical slide to which the tooth block is attached; at the opposite end of the arm is the hand wheel for radial adjustment. When the arm is adjusted it is clamped with tee-headed bolts.

Whittaker's machine is actuated by change wheels, and is of the table form. Upon a foundation or base of cast iron of large diameter the moulding table revolves, turning on a central pin, and operated with a worm wheel like Scott's, but placed underneath the table similar to Messrs. Buckley and Taylor's. A socket is bolted to one side of the foundation casting. In this socket slides vertically a pillar, which is actuated by a rack and pinion, and pinched with a set screw when at the proper height. To a flange at the top of the pillar is bolted a horizontal arm, along which moves an arm in vee'd guides, whose radial adjustment is given with a hand wheel and screw. The farther end of this arm carries a vertical slide with socket for the tooth block; therefore by means of the radial and *arc* movement of the horizontal arm, and the swivelling of the tooth block in its socket, wheels of any radius within the range of the machine table are made. The change wheels are set in a quadrant plate low down by the side of the table. An improved carrier was patented for this machine in 1884, No. 8,994, the patent consisting of a combination of two universal joints furnished with pinching screws, in order that any helical

tooth block might be so set as to be withdrawn at the particular angle most suitable thereto.

Simpson's machine, used in the States, is of a different type from anything yet employed in this country. No change wheels are used, but the pitching out of the teeth is effected on the principle of the division plate and index peg of a geometric lathe, in this case consisting of a drum of sheet iron fixed at the top of the central pillar of the machine, and perforated with a series of circles of holes giving a large range of numbers suitable for different numbers of teeth. A peg is made to fit into these holes, passing through a hole in a vertical arm, attached to the horizontal arm which carries the tooth block, and so locking the machine in position during the ramming up of each separate tooth. The horizontal or carrier arm slides vertically on the central pillar, and when adjusted for height is kept in position by means of a collar upon which it rests. A slot in the arm permits of the movement of a horizontal slide, operated radially by a screw and hand wheel. Through this slide passes a screw and a guide-rod for imparting a vertical movement to the tooth block. The tooth block is elevated by a hand wheel and mitre wheels. Provision is made by means of a quadrant-slot for setting the blocks of bevel wheels at any required degree of angle.

CHAPTER XI.

CUPOLAS AND BLAST.

ALTHOUGH for special purposes iron is sometimes melted on the hearth of the reverberatory furnace, yet for all the usual run of work the **cupola furnace** is that which is everywhere employed. Moreover, the cupola furnaces themselves which are in use to-day do not differ essentially from those of half a century ago. Better cupolas have been designed, being more economical in fuel, but the older ones retain their place, chiefly, it must be supposed, by virtue of their simplicity, and also because, in the hands of a careful furnaceman, fairly good commercial results can be obtained therefrom. Before noting some of the improvements which have been made in cupolas, I will briefly describe one of ordinary form, and of moderate capacity, such as may be seen in daily work in hundreds of foundries—that which is shown in Fig. 98.

The base *A* of the cupola is of brick, covered with a cast iron plate, *B*. The shell *C* is of boiler plate, single rivetted, lined with fire-brick, arranged as headers, set in fire-clay. In small cupolas there is only one course of bricks, in large ones they are two courses deep. The

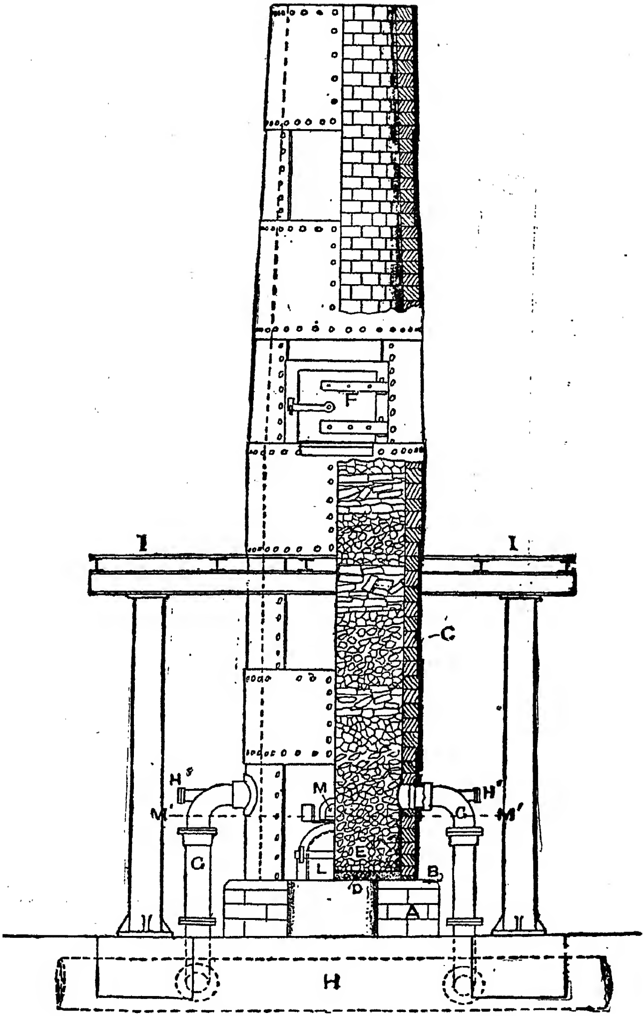
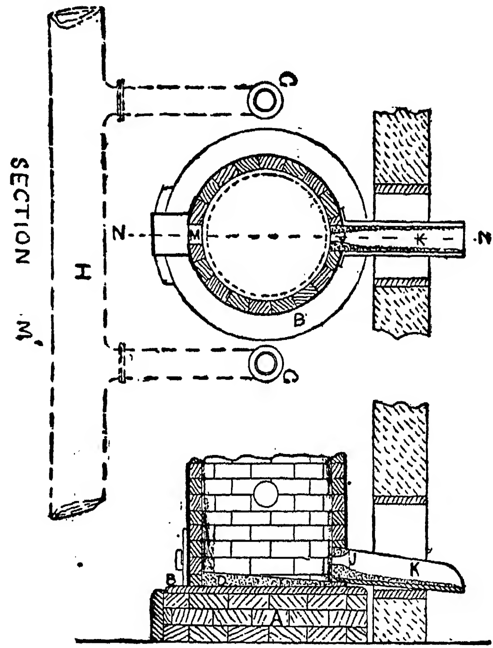


FIG. 98.—CUPOLA.
ELEVATION.

vitrified slag soon forms a glassy skin over the bricks, and thus becomes a protective coating thereto. A bed of sand, *D*, is beaten hard down on the bottom, and upon



SECTION N-N

FIG. 98.—CUPOLA. SECTIONS.

this is placed the bed charge, *E*, of coke; metal, coke, and flux alternating all the way up to the charging door *F*, which is about a couple of feet above the charging platform *I*. The blast necessary for combustion is

brought in at the two tuyere pipes *G G* from the blast main *H*, which may be placed either above the charging platform *I*, or below the ground, as shown. The metal is tapped out at the tapping hole *J*, whose spout, *K*, is usually brought through the foundry wall, outside of which the cupola is properly placed. *L* is the door closing the breast hole, through which the fire is lit, which is closed just previous to the turning on of the blast, and through which the embers are raked after the casting is done. Above the breast hole is the slagging hole *M*, placed just below the level of the tuyere openings. Through this the slag is tapped out at intervals during the process of melting.

The method of **charging** is as follows. First of all, the interior up to the height of the tuyere holes is lined for a thickness of $\frac{3}{4}''$ or $1''$ with fire-clay, or with loamy sand. The tap hole *J* is lined by ramming sand and fire-clay around a pointed bar inserted in the opening in the bricks. A fire is lit in the bottom, and a bed charge, *E*, of coke is laid upon this. Then follows a charge of iron and flux, and again a layer of coke, and so on alternately, as seen in Fig. 98. This is done two or three hours before the blast is put on, and in the meantime the various openings into the cupola remaining open, the fuel burns up quietly, and everything becomes warmed equably throughout. When the time arrives for the melting down of the metal, the breastplate *L* is lined with sand, and wedged in place, the tuyere pipes *G*, whose bends are made to swivel, are put into position and luted with clay, and the tap hole *J* being open, a gentle blast is put on

for five or ten minutes. This has the effect of hardening the clay in the tap hole. The blast is then stopped, the tap hole closed with clay by means of the bot-stick, and the full blast pressure is put on. In from ten to fifteen minutes the metal begins to run down, and presently, when the furnaceman observes through the glass or mica sight holes *H'*, *H'* of the tuyeres that the metal is getting nearly to the level of the tuyere openings, he taps out a quantity into a ladle. This is done by driving the pointed end of the bot-stick through the hard-baked clay, giving the stick a rotary motion with his hands, to enlarge the hole. The metal then runs down the shoot *K* in a steady stream, and when the ladle is nearly filled, the tap hole is closed with a daub of clay held on the flat end of the bot-stick, the stick being held diagonally downwards towards the hole at first, and then lowered sharply until the axis of the stick is in line with the hole *J*, so closing it up without risk of spluttering of the iron.

As the metal runs down, additional quantities of iron, fuel, and flux are charged in at the door *F*. Slag forms in quantity, and this has to be tapped out at intervals through the slagging hole *M*. The slagging will have to be repeated more or less often according to the inferior, or superior class of the metal. As long as slag continues to run, the hole should be left open. If very inferior or burnt iron is being melted the slag may be running nearly all the while. The economy of cupola practice is largely dependent on keeping the surface of the metal free from slag.

Charges of metal of different kinds are melted in the

cupola at the same time, by interposing between each charge a stratum of coke rather thicker than those used in the ordinary work of melting. The charge which is lowermost is then tapped out, as the charge above begins to melt, and the furnaceman is able to see the beginning of the melting of an upper charge at the sight holes H', H'.

Large quantities of metal are tapped out in detail, a ton or a couple of tons at a time, until sufficient has accumulated in the ladle. Metal in the ladle will retain its heat for a very long time if radiation is prevented by sprinkling the surface with the blowings from a smith's forge, and by allowing the oxide and scum to remain thereon.

When the melting down is done, the whole of the furnace contents are raked out through the breast hole, or, if the cupola is of the drop bottom type, like Figs. 99, 100, by dropping the bottom. Under no circumstances can the metal and fuel remain safely in a cupola long after the blast is shut off, since, if it sets, the mass will "bung up" or "gob up" the furnace, forming a "salamander," and the furnace lining may probably be destroyed in the removal of the obstruction.

The proper melting of metal is a task requiring a good deal of experience and caution. Economical melting is an excellent thing, but there are other points which have to be regarded besides the statement on paper that a ton of metal has been melted with a certain percentage of fuel. Iron may be melted so dull that poor, if not waster castings result, when a little more fuel would have dead

melted it thoroughly, producing good, sound, homogeneous castings. Then the size of the cupola, and the amount of work being done, has to be taken into account. A small cupola is more wasteful in fuel than a large one A cupola running two or three hours daily is more wasteful than one running all the day. Inferior iron is more wasteful of fuel than iron of superior quality. Hence general proportions only can be given for percentages of fuel. The total percentage of fuel to iron melted may range economically from 1½ cwt. to 4 cwt. per ton, according to circumstances. By total percentage, I include the fuel used in the bed charge. This always bears a large proportion to the total amount used, hence the reason why short meltings are so much more costly than lengthy casts. For a cupola like Fig. 98, 4′ 0″ diameter, a bed charge, *E*, of 10½ cwt. is used; for a similar cupola 2′ 4″ in diameter, a bed charge of 6 cwt. is used. But the bed charge will equal about one half the quantity of coke required for a "blow" of moderate length, say of from two to three hours.

The succession of charges in the cupolas of the two sizes above-named is as follows:—4′ 0″ cupola: bed charge 10½ cwt.; each charge of iron 21 cwt., separated by 2¼ cwt. of coke; ¼ cwt. of limestone (flux) in bed charge, and seven or eight pounds on each subsequent charge. 2′ 4″ cupola: 6 cwt. bed charge, each charge of iron 14 cwt., 1½ cwt. of coke in each subsequent charge. The first cupola will melt four tons per hour, the second from two and a half to three tons per hour. But in the first cupola, with heavy casts, twelve tons can be

melted with twenty-five cwt. of coke, including bed charges.

In cupolas such as these, doing jobbing work, using different mixtures of iron, making many light casts, and running from two to four hours per day, the conditions for economy of fuel do not exist, and as much as three cwt. of fuel per ton of metal melted will not be an unreasonable proportion. Where contrary conditions exist, the proportions may be less by nearly one half.

The chemical conditions which govern economical working are those which relate to the purity of the fuel, and to the complete utilization of the products of combustion. The coke should be the best and purest procurable, free from sulphur, hard, columnar, heavy, having metallic lustre, and clean. The height of a cupola, the position and number of tuyeres, the density of the blast, all vitally influence the ultimate results.

Height is necessary, because without it large quantities of combustible gas would escape unburnt and become lost. The process of combustion is as follows:—Air, under pressure, entering the cupola through the tuyeres, meets with the heated fuel. The oxygen in the air combines with the incandescent carbon in the fuel, forming carbonic anhydride, $C\,O_2$, a gas which will not burn. This gas takes up more carbon, becoming carbonic oxide, $C\,O$, equivalent to $C_2\,O_2$, which is combustible. If, however, this gas does not meet with sufficient free oxygen at a high temperature, it cannot burn, but will pass away, representing a certain number of heat units wasted. But if it meets with a sufficiency of heated oxygen higher

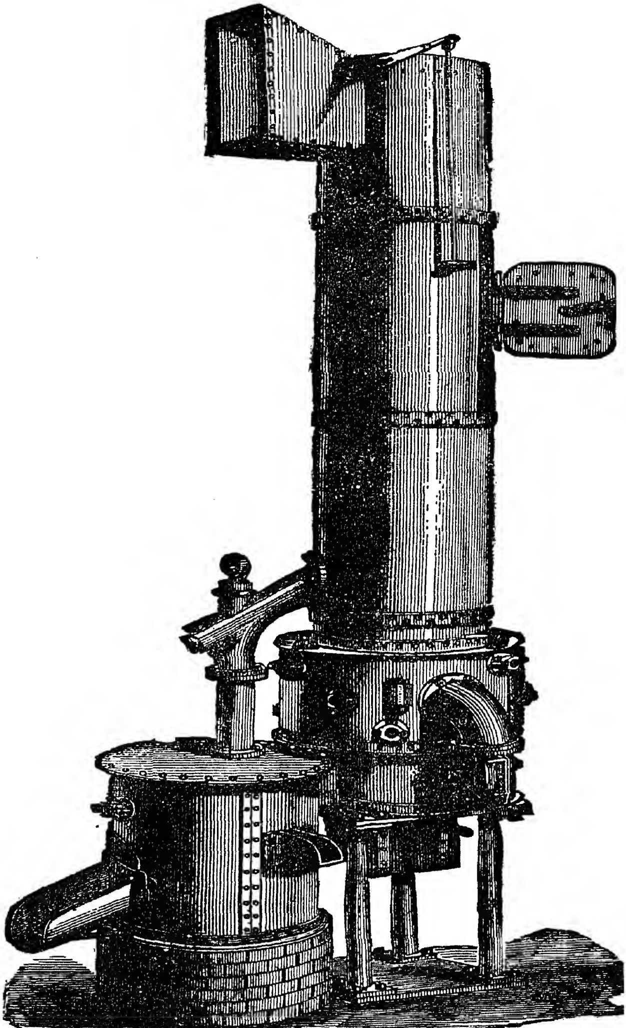


FIG. 99.—STEWART'S PATENT "RAPID" CUPOLA.

up in the furnace, it burns, giving out heat available for combustion. Hence the reason why the taller cupolas are more economical than the lower ones. Flame at, and above the charging door represents heat lost, as far as useful work is concerned. Hence also the reason why two or three rows of tuyeres, to supply the zones of oxygen necessary for combustion, have been adopted in nearly all cupolas which have been designed to supersede the older forms, a mode of construction which is therefore seen to be quite correct in principle.

The most recent, and, as I think, the best embodiment of this principle, is Stewart's patent "Rapid" cupola, two figures of which are shown (Figs. 99, 100). In this there are three zones of tuyeres enclosed by an air belt *A*, and each zone of tuyeres can be opened and closed independently of the others by means of shut-off valves. The air belt, the zones of tuyeres, and the boshes or sloping sides, are, however, of older date than this particular example. Ireland's cupolas, much used a few years since, were very tall, and were provided with boshes or sloping sides similarly to blast furnaces, by which the weight of the charge was sustained. They, or at least the earlier ones, had two rows of tuyeres, but the upper row was abandoned in later structures. Voison's cupolas were made also with air belts and with two rows of tuyeres. Numbers of common cupolas, both in this country and in America, have the same arrangement. We may mention also by the way that cupolas have been made with shifting tuyeres, so that in the absence of an air belt the tuyere pipes can be moved to the zone above or below as required.

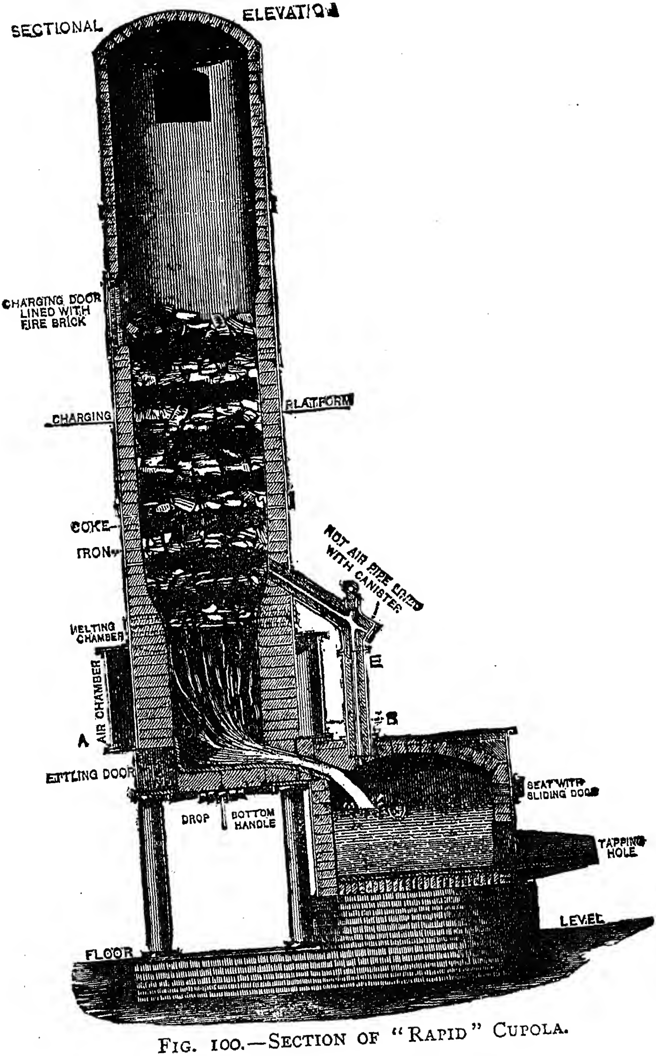


FIG. 100.—SECTION OF "RAPID" CUPOLA.

The other features of the cupola are, a brick-lined receiver for the melted metal, by which means the heat is retained and oxidation prevented, while the blast pressure maintains its surface in agitation, conducing to proper mixture and homogeneity. The waste heat therefrom is also utilized by passing up a ganister-lined pipe into the cupola, entering just above the air belt. The escape of the waste gases is regulated by a flap door at the side of the hooded top.

The efficiency of this cupola ranks so high, and it has given such satisfaction where it has been erected (as many as one hundred and eighty have been sold in a very short time, and they are still being sent to all parts of the world), that it merits a somewhat extended notice. The fact that in blows of ordinary length it is capable of melting one ton of iron with from one, to one and a quarter hundredweight of coke, speaks volumes to foundrymen. In the Appendix, p. 194, will be found an account of detailed tests to which the "Rapid" cupola has been subjected, which are well worth studying and comparing with the performances of common cupolas. A table of melting capacities and suitable sizes of blowers is also included, p. 196.

In Britain, fuel is cheap, and that, taken in conjunction with our somewhat conservative habits, no doubt goes far to account for the fact that the older and more wasteful cupolas retain their place so tenaciously in our foundries. It is a striking fact that these "Rapid" cupolas appear to be appreciated most where fuel is dearest, as in India, Brazil, etc.

/The proper pressure of blast is a matter of great importance. A soft blast will not melt the metal quickly nor thoroughly, and will cause wasteful expenditure of fuel. A sharp blast will blow away the fuel before perfect combustion ensues. Cupolas of large capacity are often made elliptical in plan instead of circular, to enable the blast to penetrate better to the interior. /

For the production of blast, fans and blowers are employed, by which the air enters the cupola under pressure. There is no virtue in mere pressure as such, but a certain rapidity of combustion is necessary in order to the efficient melting of metal. The pressure is not great, seldom more than 12 oz. per square inch, but at such a pressure an enormous volume of air passes through the tuyeres in the course of a minute. Messrs Thwaites, who are specialists in this line, give from 30,000 to 40,000 cubic feet as the volume of air necessary to melt a ton of iron, and from 20,000 to 30,000 cubic feet as that necessary to consume one hundredweight of coke. The volume of air is necessarily large, since, of the oxygen, much is lost through imperfect combustion, and the nitrogen is inert.

The difference between a fan and a blower is, that the fan acts by *inducing* a current of air, the blower produces a positive *pressure*. The fan therefore has to revolve at a very high rate of speed, causing an attendant train of evils inseparable from high speeds; the blower need only revolve at a very moderate rate. The pressure and volume are under greater control with a blower than with a fan.

The common fan is so well known that I need not illustrate it. It consists of an outer casing, cast in halves, and bolted together. Within it revolve the blades, or vanes, upon a spindle which runs in long bearings, and which is driven by belt pulleys. The revolution of the vanes produces a partial vacuum within the casing, into which air rushes from openings at the sides of the casing, gathering momentum, like a falling body, with increase of speed, and is forced out through the nozzle of the casing into the blast main.

In the blower, Figs. 101, 102, the air which enters the casing (from above in the figures) is forced forward under constant pressure by the revolving pistons or wafters into the outlet below, which communicates with the blast main. These wafters are of cast iron, shaped to templet, and fit so accurately into each other, and to the bored casing, that the thickness of a sheet of paper alone preserves them from actual contact. Being lubricated with a very thin coating of red oxide paint, they run, though practically air-tight, with the very minimum of friction. A table of the performances and other particulars of these blowers has been kindly furnished by the makers, Messrs. Thwaites Brothers, of Bradford, and is given in the Appendix, p. 196.

The attempt has been made to employ a jet of steam to induce the blast current. This was the peculiarity of Woodward's cupola.

In Herbertz's cupola also the blast is induced by an exhausting jet of steam. The jet operates in a flue near the charging door, and the blast enters through an

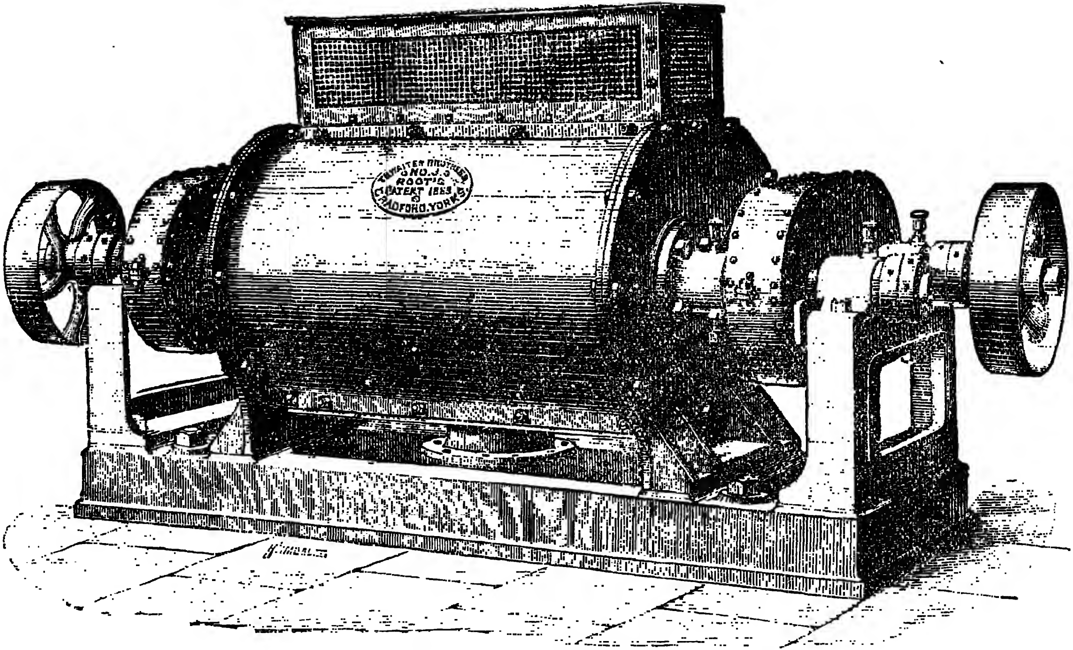


FIG. 101.—ROOT'S BLOWER.

annular opening immediately above the hearth. The width of this opening is capable of adjustment by means of screws for the production of a cutting or of a soft blast.

For the pouring of metal into moulds, ladles of various

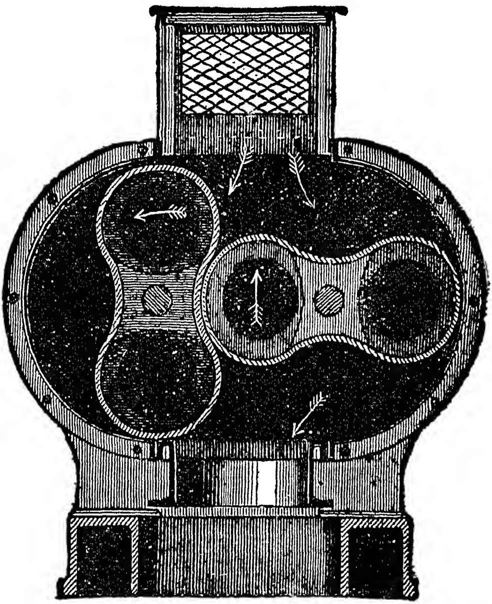


FIG. 102.—SECTION OF BLOWER.

kinds are employed. The ordinary forms are shown in the accompanying illustrations, Figs. 103-106. Fig. 103 is a hand ladle holding a half hundredweight only. It is used for very light casts, and for supplying feeder heads with hot metal. Fig. 104 shows the double handled ladle,

Fig. 103.—Hand Ladle.

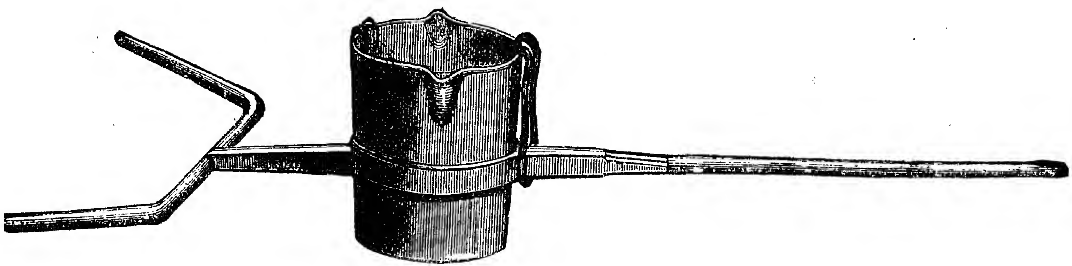


Fig. 104.—Double Handled Ladle

made in capacities ranging from one to about four hundredweights; two, three, or four men carry these ladles, according to the weight. Thus there may be one, or two men at the cross handle; and one, or two at the straight shank. When made for two, the end of the shank is turned down, and is supported on a cross bar, each end of which is held by a labourer. Fig. 105 is a heavier, or

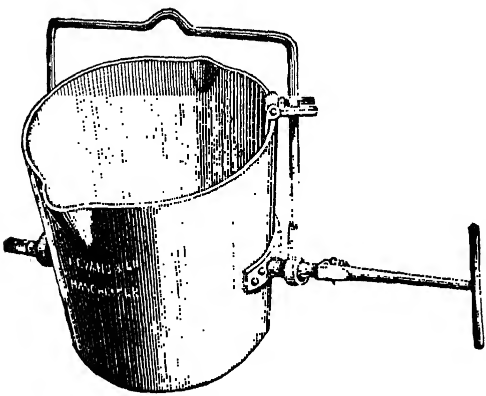


FIG. 105.—CRANE LADLE.

crane ladle, and may range from ten hundredweights to a ton in capacity. It is slung in the crane hook; the catch seen on the right prevents the ladle from becoming accidentally up-tipped, and, when thrown back, a man standing at the cross handle turns the metal into the mould. The heaviest ladles are of the type shown in Fig. 106. These are "geared ladles," and may range from one to twelve tons in capacity. The geared ladle was the invention of

Mr. Nasmyth, and a graphic illustration of the contrast between it and the old ungeared form is given in his admirable autobiography.[1] The ladle in Fig. 106 is double geared, having mitre wheels in addition to the worm gear. Many ladles have the latter only. A weight of

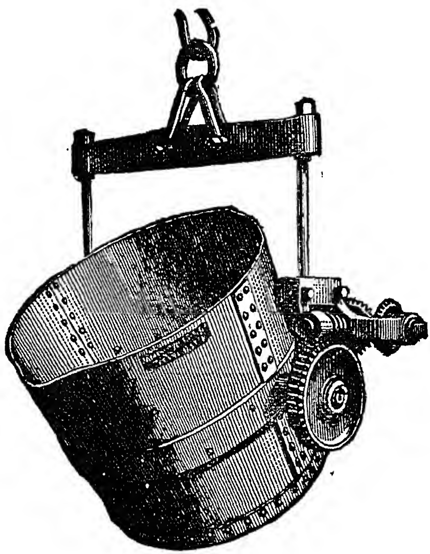


FIG. 106.—GEARED LADLE.

several tons is tipped easily and steadily into the mould by means of these geared ladles.

These ladles are, except Fig. 103, which is of cast iron, made of wrought iron plate rivetted together. The

[1] "James Nasmyth. An Autobiography," pp. 209, 210.

inside is daubed every morning before casting, with fire-clay, or loamy sand, and blackwashed. This lining is

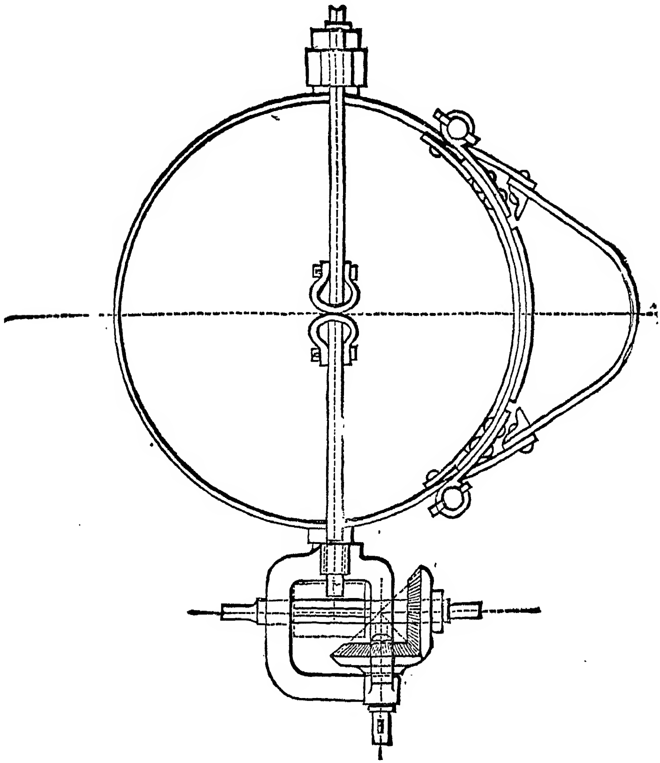


FIG. 107.—GOODWIN AND HOW'S PATENT LADLE.

dried, in the case of the smaller ladles, over a coke fire, in the larger ones by lighting a fire of wood within them.

After casting, the skulls are chipped out with a hand hammer.

When metal is poured from a ladle, a boy holds a rectangular bar of iron across the mouth, to bay back the scoriæ which floats on the surface, so preventing it from entering the mould, to the detriment of the casting. The method is necessarily an unsatisfactory one, but few attempts have been made to remedy it. Recently two forms of ladles have been patented, having a bridge or bar dividing the spout from the body; Craven and Chapman are the patentees of one; the other, Goodwin and How's patent, is here illustrated, Figs. 107, 108. From these it is seen that the body of the ladle is pear-shaped, the shell being extended on one side to form an external spout, which is separated from the body by a removable skimmer or dividing plate, projecting above the top of the shell, and descending to the required distance from the bottom. It is held in position by eyes, pins, and cotters at the top, and by finger plates at the bottom. The skimmer plate is readily removable for repairs. The principle of taking the metal from the bottom is an excellent one, and has long been adopted in the steel casting ladles, fitted with a goose neck and plug.

The cranes used in foundries are of three kinds—post cranes, which slew completely round; wall cranes, which slew within a limited range; and overhead travelling cranes, the range of whose travel covers the whole of the floor area of the shop. The post cranes are very useful when the shop is of moderate size and of quadrangular

form. The framework, triangular in outline, may be constructed either of wrought iron or of wood. The

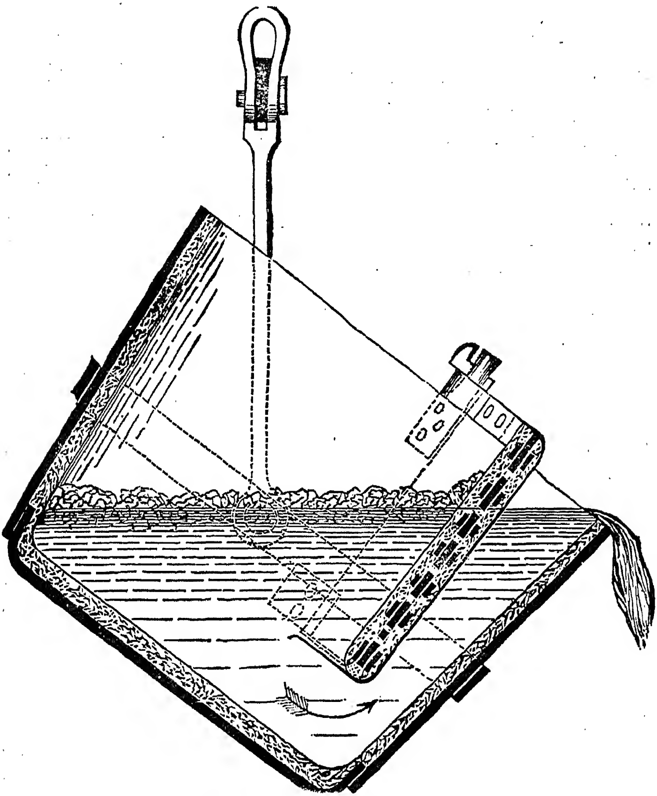


FIG. 108.—SECTION OF PATENT LADLE.

post is pivoted in a toe step in the ground, and in a socket attached to cross timbers in the roof trusses.

There is provision for lifting by single and double gear, and for racking inwards and outwards; the latter provision being quite essential for the precise adjustment of the ladles in relation to the moulds, which are arranged about on the floor. The power of cranes such as these may range from three to fifteen tons.

The wall cranes are necessarily of light construction, ranging between powers of one and two tons only. The framework consists of horizontal jib, and ties only, made in wrought iron. The hoisting gearing is attached to a bracket which is bolted to the wall, independently of the main framework. A racking carriage travels on the horizontal jib, and is worked by means of an endless rope depending from a spider wheel above. These are used for turning over and lifting the light moulds, and smaller ladles, and if ranged in series, each within range of the radius of its fellow, ladles can be passed down the shop rapidly, being transferred from crane to crane with changing hooks.

But the overhead traveller form, has the best arrangement for all except the smallest shops. The traveller moves along the gantry beams which are supported on the stone abutments of the walls, and the crab has a transverse motion across the traveller beams. The whole area of the floor can thus be covered at will. Travellers when of small size are worked by hand from below with endless ropes, those of larger size by a man stationed on the crab above. The heaviest travellers are actuated by steam, either from a pair of engines affixed to the crab, or preferably from independent engines, motion being

transmitted therefrom through the medium of fly-ropes of hemp or cotton; the latter type is that in most favour, and appears to be rapidly superseding the older types of hoisting machines in shops for which rope transmission is suitable.

CHAPTER XII.

IRON, ETC.

Cast iron owes its value as a material of construction to the fact that it is not pure metal. If it were pure, it would be useless for the purposes to which it is now applied. Pure iron cannot be melted to fluidity, neither when cold is it rigid nor hard, but ductile and soft in comparison with commercial iron. Cast iron does not contain more than 93 or 94 parts of pure metal in the 100, the remaining 6 or 7 consisting of carbon, silicon, phosphorus, sulphur, and manganese, with occasional percentages of arsenic, titanium, and chromium.

The element which more than any other influences the character of cast iron, is **carbon**, and this occurs in allotropic forms, either as graphite or plumbago, in a state of mechanical admixture, forming grey iron; or as combined or dissolved carbon, producing white iron. In most, if not all commercial irons, the carbon occurs in both forms. The proportion of combined carbon is never more than a mere trace in the first, while the second is almost destitute of graphitic carbon. The mottled varieties of iron occupy a position midway be-

tween the grey and white, and are to be regarded as mixtures of the two kinds, the mottle being more pronounced as the proportion of white increases. Here, too the proportions of combined and graphitic carbon become nearly equalized. Grey iron is the most fluid, but is the weakest. White iron runs pasty, and is strong, but brittle. Mottled iron melts very well, and is both strong and tough.

Iron is strong, and adapted for general engineers' work in proportion to its amount of mottle, highly mottled iron being correspondingly prized by foundrymen.

There are several varieties of pig supplied by the ironmasters, ranging from the No. 1 Clyde, which is the greyest iron, to the forge pigs, which are white irons. (See Appendix, p. 199.) Hence it is possible to obtain pigs suited to almost any class of work, being either used alone, or by intermixture. In foundries where the same class of castings is being constantly turned out, this is what is done; but in general foundries, where all kinds of castings are required in grey, white, and mottled iron, in all their grades, usually three or four kinds of pig only are kept in stock, and the numerous grades of metal required from day to day, or during the same day, are prepared by admixture of pig with scrap. It is in these mixtures that the skill of the practical foreman or furnaceman is seen, skill which comes only after long experience. There are many moulders who would not know how to mix metals to produce definite grades, and no rules can be laid down for this work except those of a somewhat general character. Thus it is easy, having ascertained

the metal which results from the mixture of certain pigs in certain definite proportions, to repeat the operation as often as required, since a grade of pig of a given brand is fairly though not absolutely constant in character. But when scrap is used, the quality of each separate piece of scrap has to be estimated by its behaviour under the sledge, and by the eye. The use of scrap, if purchased judiciously, and mixed by a competent man, is more economical than that of pig, and there is therefore advantage in its employment. Every furnaceman and foreman should therefore learn to judge of the quality of scrap and pig, and the effect of their intermixture. Afterwards he may test the results experimentally at the testing machine; but he must know how to mix, or the testing machine will only record failures.

I will briefly note the most characteristic features of the typical varieties of iron, but they must be studied in a practical manner in the founder's yard.

Grey iron on being struck with a sledge fractures easily, and presents a highly crystalline structure, with a somewhat dull bluish grey metallic lustre. If very dull, the metal is inferior, and poor in quality.

Iron follows the same law of crystallization as other substances. The slower the rate of cooling the larger the crystals produced. If a newly fractured surface of grey iron is shaded by the hand, and so viewed with reflected light only, the crystals of graphite become visible, appearing as black lustrous patches amongst the iron. If a portion of the iron is crushed and levigated, the graphite will float on the surface of the

water. When the metal is molten it lies quietly in the ladle, breaking into large striations, without sparks or disturbance. After standing awhile it becomes covered with scum, composed of scales of graphite which have separated and floated to the surface. When cast, it runs fluid, and takes the sharpest impressions of the mould, being thus adapted for the finest castings. It is only moderately contractile. At the testing machine it breaks with a very moderate load, undergoing however a considerable amount of deflection first.

Now, if we take **white iron**, whether in the form of pig or of scrap, and fracture it, we find that it requires more force than the grey to effect fracture, but that it breaks very short and clean. An inspection of the fractured surface reveals a highly crystalline structure, but the crystals are long, fine, and needle-like in character, and of a bright, almost silvery-like lustre: no scales of graphite can be detected. The melted metal when in the ladle, though thick and somewhat viscous by comparison with grey iron, is in a state of violent ebullition; boiling, bubbling, and throwing off a quantity of sparks or jumpers. It does not run well except in considerable mass, and is highly contractile. Unlike the grey iron, it cannot be shaped with the chisel and file. At the testing machine it sustains a greater load before fracture than grey iron, but breaks with less deflection.

The **mottled iron** being a mixture of grey and white, we find that it partakes more or less of the characteristics of each, and is therefore better adapted for most castings than either of those alone. Considerable force is required

to fracture a good sample of mottled iron, and when the broken surface is examined it presents that peculiar mottled appearance from which it derives its name. The crystals are of the same form as those in grey iron, but smaller, and the dull bluish lustre of that is replaced by a more silvery hue. The colour alternates, being patchy, the white contrasting with the graphitic scales still present. It melts and runs well, is tolerably quiet in the ladle, is moderately contractile, takes a high strain and a good deflection at the machine.

Now there are several grades both of grey, mottled, and white irons, and the skill of the furnaceman consists in judging of the minute differences in these and utilizing them accordingly.

There is a kind of iron often found along with scrap, and hated by furnacemen, known as **burnt iron.** It is iron which, having been long subjected to an intense heat below the melting point, has lost much of its metallic character, being largely in the condition of oxide. It is of an earthy red colour, and is found in scrap containing old fire bars, sugar and soap pans, retorts, and furnace grates. In the furnace it does not melt freely, but becomes viscous or pasty, and chokes the tuyeres and the fuel. In a furnace using much of this, the slagging hole has to be kept open during nearly all the time of melting, and much of the iron mixes with and runs away to waste with the slag. It damages the furnace lining, and when poured runs abominably thick, and produces almost white, but rotten castings. Burnt iron can only be properly utilized by admixture in slight proportions with good open grey pig.

Repeated **re-melting** of grey iron tends to inc-ased strength, at the sacrifice of toughness and elasticity, the re-melted metal approaching to the white conditi. Hence, after two or three re-meltings, more open pi should be added to preserve the toughness of the metal.

It is by admixture therefore that all the qualities of cast iron for foundry service can be obtained, and it is true economy for a founder to keep a good stock of scrap and pig for use for his varied day to day requirements.

The difference in the qualities of these mixtures is, as we have stated, due largely to the amount and manner of occurrence of carbon. In reference to the remaining constituents of commercial pig, and the question of their relative influences upon the metal, we will not enter exhaustively. Such matters concern the chemist, the metallurgist, and iron smelter, rather than the founder, who can exercise no control over them. If they are in his pig he cannot eliminate them, and can scarcely, if at all, modify their effects by admixture. It will be sufficient for our purpose therefore to note very briefly the leading facts which it is convenient that the founder should be aware of in relation to these, and then pass on to the tests applied to cast work.

Silicon is one of the most enigmatical substances found associated with cast iron. Formerly silicon was regarded as an enemy, producing brittle and poor metal. Now, M. Gautier, and Messrs. Stead, Turner, and Wood, recognize in it a friend; for by mixing certain proportions of silicon with white and burnt iron they are able to convert it into grey, the silicon throwing

down carbon from the combined to the graphitic condition.

Phosphorus is always present in pig, and does no harm so long as it does not exceed 0·5 or 0·75 per cent.; a higher proportion tends to brittleness. Phosphorus however renders iron fluid, and this is an advantage for small castings, but at the same time it renders them hard.

Sulphur in small quantity produces mottled iron, separating carbon as graphite, but in excess it causes the iron to become white.

Manganese is undesirable, producing a weak and white iron.

There is no question that the period of empirical mixing and judging of cast iron will come to a close in the immediate future. The researches of Messrs. Stead, Turner, Gautier, and Keep, are fraught with vital interest to the ironfounder, and at least for special classes of work, if not for the average run of castings, it is all but certain that results the most precise will be shortly attainable. A few remarks on certain recent developments and researches must close this section upon iron.

In a paper read before the 1888 August meeting of the American Association for the Advancement of Science, Mr. Keep, of Detroit, Michigan, detailed the results of numerous experiments undertaken with a view to determine the precise influence of **aluminium** upon iron, experiments which, taken in conjunction with the known extreme carefulness of the tests applied and the recent adoption on a large scale of the Castnar and Cowles

processes for the production of pure aluminium and its alloys, appear to be fraught with much promise.

It has long been known that a very small percentage of aluminium, so little indeed as ·01 per cent., suffices to render molten wrought iron very fluid, and to prevent blow holes in steel castings. It is equally beneficial in cast iron, in what precise way is not certainly known, but probably it operates much like silicon, by causing the comparatively inert carbon to assume the graphitic form.

Mr. Keep experimented on this subject to determine the various points by which founders estimate the value of an iron. Thus, using white iron as a base, an addition of ·01 per cent. of aluminium increased the strength to resist a dead weight by 44 per cent., and to resist impact by 6 per cent., and he proved that the aluminium remains in the metal, and exerts its influence in subsequent casts. Mr. Keep considers that the capacity to resist impact is a better test of the quality of an iron than the capacity to resist dead weight, and he states that with certain percentages of aluminium the first result can be attained.

Aluminium causes iron at the instant of solidifying to throw out a portion of its combined carbon into the graphitic condition, producing grey iron. The formation of the graphite is also so uniform that the thin portions of the castings are as grey as the thicker portions. In this respect it resembles silicon. Since the aluminium sets free the carbon at the instant of solidification there is less tendency to chill, which result is caused by the

running of metal against a cold surface, and the consequent imprisonment of combined carbon before it has time to separate as graphite.

When aluminium causes the separation of the carbon at the instant of solidification, the scales of graphite at the surface of the casting act similarly to blackening, protecting the surface from becoming sand-burnt, and therefore producing a softer skin for cutting tools.

The presence of aluminium, by making the grain closer and finer, gives greater elasticity, and reduces the permanent set.

The shrinkage of iron is lessened by the use of aluminium. This might naturally be expected, knowing, as we do, that grey iron is much less contractile than white. It is a distinct advantage, as lessening shrinkage strains on disproportionate castings.

The question of fluidity is scarcely settled. Using white iron, the fluidity of the metal was increased by the addition of aluminium; using grey, it was diminished. The use of aluminium therefore permits fine castings to be made with white iron, which without such addition could not possibly be made.

It is at the **testing machine** that the precise value of any mixture of metal made is ascertained, and no foundry of any pretensions can afford to be without such an instrument. Testing, in the hands of such men as Professors Unwin or Thurston, has become a scientific work, in comparison with which that of the foundry is rough and approximate only. But this is nevertheless sufficiently accurate and adequate for its purpose.

The common method of testing is to cast bars having a section of $2'' \times 1''$, and a length of $3' 2''$. These are placed upon supports $3' 0''$ apart, the $2''$ being in the vertical direction, and loaded until they fracture. Fracture in a good bar should not take place with a less load than 30 cwt., in exceptional instances it goes as high as 33 or 35 cwt.; 25 to 28 cwt. would indicate a poor bar. The amount of deflection is also noted, as being a measure of the elasticity of the metal. It should not be less than $\frac{3}{8}''$, and will in good bars be as high as $\frac{1}{2}''$. The behaviour of bars cast from the same ladleful of metal in the same set of moulds will often be found to vary, fracture variously occurring within a range of 2 or 3 cwts.; hence it is the practice to cast several bars for testing, and take the average of the whole. Test bars should be cast from the same metal, under the same conditions of melting, as the work for which they afford the test, and should be stamped or labelled with the date, and all particulars deemed of service. Test bars should be cast in the same manner as the work of whose strength they are to be the index, in dry sand if the work is in dry sand, in green sand if that is in green. The relative strength of test bars will be affected by difference in dimensions, a bar of small area being relatively stronger than one of larger area, the reason being that the chilling effect of the sand hardens the outer skin, and so raises slightly its tensile strength. That which is regarded as the **standard bar** is $1''$ square and $1'$ long. This sustains about one ton before fracture. Pounds weight on this bar divided by 84 give hundredweights on the $36'' + 2'' + 1''$

bar; and hundredweights on the latter multiplied by 84 give pounds on the former.

French ironfounders employ a **falling test.** The test bar is 40 mm. square (1·57″) and 250 mm. long (9·84″), and is supported on knife edges 160 mm. apart (6·29″). A weight of 12 kilos (26·44 lbs.), having its lower end bevelled, and terminating in a narrow blunt ridge, is allowed to fall upon it, its fall being controlled by vertical guides. Such bars, of good average foundry quality, fracture under the impact of a blow delivered from a height of 65 to 75 centimetres, the distance being measured from the top of the weight. 70 cm. (27·5″) fall indicates a good bar.

Fig. 109 illustrates a **bar tester** manufactured by Messrs. W. and H. Bailey, of Salford, Manchester. This patent Transverse Tester is a valuable adjunct to the offices of iron works, etc. Its easy manipulation, and the rapidity with which it can be worked, have made it exceedingly popular, and it is now used by many large firms. Very often there is a total absence of information among ironfounders as to the qualities of the cast iron they use. This enables experiments to be made without trouble, and will be found a ready means for accurately ascertaining the value of different mixtures. There are two sizes of this Tester made, one for bars 3′ long × 1″ square, and the other for bars 3′ long × 2″ deep × 1″ thick. This Tester is also made with or without the self-registering weight and lever. It will be observed on looking at the illustration that there is a rack on the lever. A milled head on one of the hands

can be turned round with ease; this propels the weight along the lever. When the material breaks the dials indicate the pounds weight. It will be noted that the experimentalist, by having both his hands at work, one taking up the strain and the other propelling the indi-

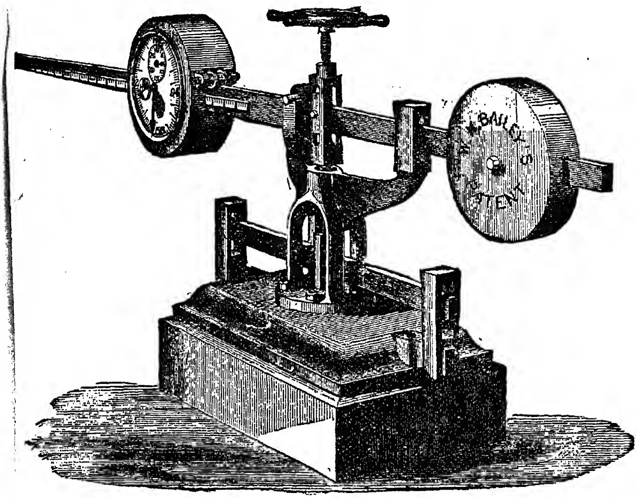


FIG. 109.—BAR TESTER.

cating weight, can thereby obtain exact results quicker than by any system with loose weight.

The tests employed by **Mr. Keep**, of Detroit, Michigan, are far more elaborate and definite than any commonly employed in this country. The test bars proper are $\frac{1}{2}''$

square and $12\frac{1}{8}''$ long. They are tested both by a gradual load, and by impact. A "fluid strip" $1''$ wide and $\frac{6}{100}''$ in thickness is cast and run to test the fluidity of the iron. A "crook strip," that is, one having a rib along one side, is also cast to test the amount of the tendency of the iron to curve. The nicest wedge measurements are employed to learn the amount of shrinkage and curving. The amounts of deflection of the test bars under impact are also recorded upon a sheet of paper.

It is necessary for the moulder to be able to estimate the probable weight of a casting from the dimensions of the pattern or the mould, in order to know how much metal to melt down and tap into the several ladles. It sometimes happens that a careless moulder will make a waster casting simply through not having enough metal in the ladle to fill the mould. This is quite inexcusable. Calculation need not be very exact, because there is always a considerable margin allowed for runners and risers, so that if a calculation is made within several pounds in light work, and even hundredweights in heavy work, it is sufficient for the purpose of the moulder.

The estimation of the number of cubic inches or of cubic feet in a mould is the necessary basis of calculation, a cubic inch or foot of average cast iron weighs a certain amount, and the total cubical contents multiplied by this unit weight gives at once the weight of the casting. Mensuration therefore is wanted, but only of a very simple character.

Some of the principal rules of mensuration are summarized in the Appendix, p. 200, for convenience of reference. It is very often the case that the forms of castings are

such that they cannot be referred to any definite mathematical figures. Then they must be divided out into the nearest approximate forms—rectangles, triangles, surface areas, segments, etc.—and the sum of the several sections added together. Sundry useful tables to facilitate calculations of this kind are given in the Appendix.

When iron is poured into metallic moulds instead of into those of sand, the result is that the surface of the casting so poured becomes of a steely character, so extremely hard that no cutting tool will attack it, and more durable, more capable of resisting the action of friction, than steel itself. It is believed that this **chilling**, as it is called, takes place in consequence of the combined carbon in the iron not having time to separate out as graphite. Poor irons will not chill deeply. To produce chilling of $\frac{1}{2}''$ or $\frac{3}{4}''$ in depth, the metal must be tough, strong, mottled. A strong iron is also necessary, because there is tremendous stress in a chilled casting, owing to the inequality in the shrinkage strains in the contiguous portions, which are rapidly and slowly cooled.

The iron for chilling should not be poured very hot, but dull, it will then lay more quietly in the mould. The chill should also be heated in the stove to so high a temperature that it cannot be touched with the hands. To pour metal into a cold chill is always dangerous. The surface of the chill is protected with a coat of black wash or other refractory material. In no case should the metal be allowed to beat long against a localized spot, as burning of the chill and partial fusion of the same to the molten metal is certain to ensue. The mass of metal in a chill should be large. The chill should

always be much heavier than the casting which has to be poured into it: without sufficient mass, fracture is almost certain to occur.

Burning on signifies the mending of fractured castings, or imperfect castings due to incomplete running, by a process of autogenous soldering of metal to metal. It is simply this, that sufficient molten metal is poured over the surface against which the union has to be effected until local fusion has taken place. Then the pouring is stopped, and the casting is afterwards as strong there as elsewhere. The danger is lest the local increase in temperature should cause fracture of the casting to occur in the vicinity.

Before commencing to burn on, the casting is heated in the drying stove, brought out, imbedded in the floor, and the particular locality where the fusion is to take place is heated with red-hot weights placed in proximity thereto. This is done to diminish risk of fracture. Sand or loam cake is built up around the spot where the new portion has to be burned on, and is shaped into the particular outline required. A gutter or channel is cut leading away from this. The molten metal is now poured gently and slowly over the fractured surface, and allowed to run away through the gutter. The heat of the metal soon produces fusion of the surface, and as soon as the moulder learns by trial with the end of a rod that fusion has taken place, he ceases pouring. To burn on only a few pounds of metal several hundredweights have to be run over the surface into the gutter. This is broken up afterwards.

APPENDIX.

TABLE I.

Sand Mixtures.

THESE mixtures, as stated in Chapter II., p. 9, are given as typical and illustrative only of the manner in which moulding materials are prepared to suit the ever-varying requirements of the foundry. Only from this point of view are they to be regarded as of value.

Two mixtures of strong sand from the Manchester district are :—

(1) 2 barrows of red sand.
2 „ road „
2 riddles of horse-dung.
5 buckets of coal-dust.

(2) 2 barrows of red sand.
4 „ ground road sand.
5 sieves of coal-dust.
1 „ black sand.
1 „ loam.

Jobbing or common sand :—

4 barrows of red sand.
2 „ ground road sand.
2 „ black sand.
6 sieves of coal-dust.

For small work :—

3 riddles of red sand.
3 „ road „
3 „ fine yellow sand.
3 buckets of fine coal-dust.

For fine wheels :—

3 riddles of red sand.
3 „ fine yellow sand.
2 buckets of fine coal-dust.

In the West of England. Strong sand :—

2 barrows of Seend sand.
1 „ Devizes sand.
2 „ loam.
5 buckets of coal-dust.
2 sieves of horse-dung.

Sand for light work :—

5 barrows of black sand.
5 „ Seend „
3 buckets of coal-dust.

Loam :—

1 barrow of black sand
1½ „ Seend „
½ „ Devizes sand.
18 shovels of dung.

The above mixture with *half* the amount of dung makes a good *core* sand.

The core sand used at Banbury is composed of equal parts of burnt sand and a porous red sand obtained in the vicinity of Birmingham. The dry sand is composed

of the core sand ground in a mill and thickened with clay-wash. The red sand is largely used in Birmingham and Manchester, and, like the Worcester sand, which it resembles, is very free and open, being largely self-venting.

In the Bradford district (Yorkshire) a red sand from the Doncaster district is employed for general jobbing work; it is fairly open.

"Winmoor," a very open gritty sand, is used for strong green sand moulds.

A yellow sand from Kippax is used for cores and for dry sand work.

For loam: Doncaster or Kippax sand is ground with clay-wash, and horse-dung or cow-hair added.

Mansfield sand (Nottinghamshire) is used for fine work; it is a close sand. This is also used in the Eastern Counties. A little old sand is mixed with the above, according to the class of work.

The following are from foundries in Bradford:—

(1) Ordinary green sand is composed either of Pontefract, Doncaster, or Snaith sand, mixed with 50 per cent. of old sand, and 1 part of coal-dust to 8 or 10 of sand, according to weight of casting.

(2) Fine green sand for small moulds and teeth of wheels is composed of Mansfield sand, with from 25 to 50 per cent. of old sand, and 1 part of coal-dust to 15 of sand.

(3) For cores: Pontefract, Doncaster, and Snaith sands are used, provided they are free from clay.

(4) For large cores: dried loam pounded, and horse-

dung dried and sieved, are mixed with the above sands in various proportions.

(5) Dry sand: for facing—dried loam pounded, and brought to consistence of green sand; for box filling—old and new sand mixed, and weak clay-wash added.

From another firm I have—

(1) For common green sand: yellow sand from Kippax, and red sand from Snaith and Doncaster, each mixed with old sand in different proportions, according to the quality of the work.

(2) For fine wheels: Mansfield sand.

(3) Strong sand is prepared from Buttershaw sand mixed with old sand, and coal-dust in varying proportions.

(4) Cores: red sand, or yellow sand, mixed with a little clay and old sand.

From a Leeds firm:—

(1) Common green sand: two-thirds of old sand to one-third of new yellow sand; coal-dust to suit work.

(2) Strong sand: one-half old sand, one-quarter yellow, and a quarter red; coal-dust in varying proportions.

(3) Core sand: two-thirds yellow sand, and one-third dung.

In the London district Erith sand is largely used; in Scotland, Belfast and Falkirk sands; each district and each shop having its own special mixtures; but the foregoing will suffice to illustrate the method of mixing.

TABLE II.

PARTICULARS OF STEWART'S PATENT "RAPID" CUPOLAS.

No. of Cupola.	Diameter of Shell.		Total Height from Ground.	To Melt Tons per hour.	Approximate Weight complete with Receiver.	Weight.	Size of Blower Required.
	Ft.	In.	Feet.		Cwts.	Tons.	No.
$\frac{1}{2}$	1	9	13	$\frac{1}{2}$	28	2	2a
$\frac{3}{4}$	2	0	15	$\frac{3}{4}$	32	$2\frac{1}{2}$	1a
1	2	4	18	1	37	3	1
2	2	6	20	2	42	$4\frac{1}{2}$	2
3	3	0	21	3	57	6	2
4	3	6	22	4	74	$7\frac{1}{2}$	3
5	4	0	23	5	97	9	3
6	4	6	24	6	120	12	4
8	5	0	26	8	172	15	4
10	5	6	28	10	215	18	5

TABLE II.—*continued.*

CERTIFIED TEST OF STEWART'S PATENT "RAPID CUPOLA NO. 4, AT MESSRS. RUSHFORTH & CO.'S, ST. JAMES'S FOUNDRY, BRADFORD, JUNE 26, 1885.

	Time.	Charge of Coke in lbs.	Charge of Iron in lbs.
Time of lighting fire	12 30	336	2240
Put in coke for bed of cupola	1 0	112	2240
Making up door	1 30	112	2240
Commenced charging	2 40	112	2240
Filled up cupola	3 0	112	2240
Commenced blasting	3 3	112	2240
Metal running down	3 8	112	2240
Took away two tons of metal in		112	2240
twenty-six minutes after blasting	3 29	112	2240
Took away 15 cwt. at	3 38	1,232	20,160
" 2 tons at	4 7		
" 2 " 5 cwt. at	4 35		
The remainder in hand ladles			
Finished charging	4 35		
Finished blasting	5 35		

Fuel used for bed coke	336 pounds.
Fuel used for fusion coke	896 "
Total consumption of fuel	1,232 pounds.
Amount of iron melted in cupola	20,160 pounds.

TABLE II.—*continued.*

NO. 3 "ROOTS" BLOWER.

Speed of Blower in Revolutions.	Pressure Water in Inches.	Time when taken.	Cubic Feet of Air per Ton of Iron Melted.	Cubic Feet of Air per Cwt. of Coke consumed.
377	18	3·10	40,738	33,331
385	34	3·40		
391	28	4·25		

REMARKS.

This was a melting of nine tons of iron with 1,232 lbs. of coke, in two hours and thirty-two minutes' time from starting to finishing blasting; but during the blow, blast was stopped twenty-eight minutes. Total time the blast was on, two hours and four minutes. Blast stopped for thirteen minutes at 4.7, five minutes at 4.35, and ten minutes at 4.55—not being able to take away the metal fast enough.

One ton charge of iron consisted of 10 cwt. machinery scrap and 10 cwt. of Stanton pig iron. The coke used was in 1-cwt. charges, of good quality, Bearpark Brand, supplied by Messrs. Newburn Brothers.

NOTE.—16·36 lbs. of iron to 1 lb. of coke.

NOTE.—Coke used exclusive of bed, 896 lbs. And amount of iron melted, 20,160 lbs.; or 1 cwt. of coke per $22\frac{1}{2}$ cwts. of iron.

TABLE III.

PARTICULARS OF ROOTS' PATENT IMPROVED ROTARY BLOWERS.

Number of Blower.	Melting Iron.				Blacksmiths' Fires.			General Dimensions.						
											External Dimensions of Packing Case.			
	Maximum Number of Revolutions per Minute.	Tons of Metal per Hour.	Adapted to "Rapid" Cupola, diameter inside at Tuyeres.	Adapted to "Rapid" Cupola, diameter outside of Shell.	Number of Blacksmiths' Fires.	Approximate Nominal Horse Power.	Volume of Blast in cubic feet delivered in one Minute.	Diameter of Delivery Orifice.	Diameter of Pulleys.	Breadth of Pulleys.	Length.	Breadth.	Height.	Approximate Weight.
								In.	In.	In.	Ft. In.	Ft. In.	Ft. In.	Cwts.
4A	[illegible]	½ }	10 in.	21 in.	3	¼	350	4	8	2½	2 7	2 9	2 4	5
3A	[illegible]	¾ }	12 in.	24 in.	4	½	460	4½	8	2½	2 9	2 9	2 4	5½
2A	350	1 }	14 in.	28 in.	6	¾	600	5	8	2½	2 11	2 9	2 4	6
1A	350	1½ }			8	1	800	6	10	3	3 2	2 11	2 4	6¼
1	400	2	16 in.	30 in.	13	2	1300	7	10	3	4 8	2 11	2 4	9
2	400	3	18 in.	36 in.	20	4	2000	8	12	3¼	5 3	3 4	2 7	13
3	[illegible]	4	20 to 22 in.	42 to 48 in.	30	6	[illegible]	10	14	4	6 4	3 4	2 8	15½
4	[illegible]	7	28 to 32 in.	52 to 60 in.	50	8	[illegible]	12	16	5	8 2	4 4	3 5	28
5	[illegible]	10	35 in.	66 in.	70	10	[illegible]	13½	18	5½	9 2	4 5	3 6	32
6	310	15	38 in.	72 in.	90	12	[illegible]	17	20	6½	9 5	5 4	4 6	52
7	300	20	43 in.	84 in.	120	14	[illegible]	19	22	7	10 8	5 7	4 6	60
8	[illegible]	25 }			140	17	[illegible]	22	24	9	12 0	5 7	4 6	75
9	[illegible]	30 }	For two or	more cupolas	170	19	[illegible]	24	27	10	12 0	7 6	7 0	90
10	240	38 }			200	22	19200	26	27	10	13 0	7 6	7 0	110

TABLE IV.

SIZES, WEIGHTS, PROOF STRAINS, AND WORKING LOADS OF SHORT LINK CRANE CHAIN.

Size of Chain.	Approximate Weight per Foot in lbs.	Proof Strain in Cwts.	Working Load in Cwts.
$\frac{3}{8}$	1·33	36·75	20·0
$\frac{7}{16}$	1·91	45·0	24·0
$\frac{1}{2}$	2·33	65·5	27·0
$\frac{9}{16}$	3·25	75·0	44·0
$\frac{5}{8}$	3·66	102·0	53·0
$\frac{3}{4}$	5·33	147·0	80·0
$\frac{7}{8}$	6·71	200·0	110·0
1	9·33	268·0	140·0
$1\frac{1}{8}$	11·9	334·0	180·0
$1\frac{1}{4}$	14·5	408·0	220·0

TABLE V.

SIZES, WEIGHTS, WORKING LOADS, AND BREAKING STRENGTHS OF HEMP ROPES.

Circumference in inches.	Weight per Fathom in lbs.	Safe Working Loads in Cwts.	Breaking Strain in Cwts.
$2\frac{3}{4}$	2·0	6	40
$3\frac{3}{4}$	4·0	12	80
$4\frac{1}{2}$	5·0	18	120
$5\frac{1}{2}$	7·0	24	160
6	9·0	30	200
$6\frac{1}{2}$	10·0	36	240
7	12·0	42	280
$7\frac{1}{2}$	14·0	48	320
8	16·0	54	360
$9\frac{1}{2}$	22·0	78	520
10	25·0	84	560

TABLE V.—*continued.*

SIZES, WEIGHTS, WORKING LOADS, AND BREAKING STRENGTHS OF ROUND IRON WIRE ROPES.

Circumference in inches.	Weight per Fathom in lbs.	Safe Working Loads in cwts.	Breaking Strain in cwts.
1	1·0	6	40
1½	1·5	9	60
1¾	2·5	15	100
2	3·50	21	140
2¼	4·50	27	180
2½	5·50	33	220
2¾	6·50	39	260
3	7·50	45	300
3¼	8·50	51	340
3½	10·50	60	400
3¾	12·0	72	480
4	14·0	84	560
4½	18·0	108	720
5	22·0	125	900

TABLE V.—*continued.*

SIZES, WEIGHTS, WORKING LOADS, AND BREAKING STRENGTHS OF ROUND STEEL WIRE ROPES.

Circumference in inches.	Weight per Fathom in lbs.	Safe Working Loads in cwts.	Breaking Strain in cwts.
1	1·0	9	60
$1\frac{1}{4}$	1·50	15	100
$1\frac{1}{2}$	2·0	21	140
$1\frac{3}{4}$	2·50	27	180
2	3·50	33	220
$2\frac{1}{8}$	4·0	39	260
$2\frac{1}{4}$	4·50	45	300
$2\frac{3}{8}$	5·0	51	340
$2\frac{1}{2}$	5·50	60	400
$2\frac{3}{4}$	6·50	72	480
$3\frac{1}{4}$	8·50	84	560
$3\frac{3}{8}$	5·0	90	600
$3\frac{5}{8}$	10·50	100	720
$3\frac{3}{4}$	12·0	115	840
4	14·0	126	960

TABLE VI.

AVERAGE COMPOSITION OF PIG IRON.

	Grey.	Mottled.	White.
Graphitic carbon.	3·10	1·99	2·42
Combined carbon	0·04	2·78	
Silicon	2·16	0·71	0·36
Sulphur	0·11	trace	0·87
Phosphorus	0·63	1·23	1·08
Manganese	0·50	—	—
Iron.................	94·56	93·29	95·27

TABLE VII.

MENSURATION.

I.—AREAS.

1. **Rectangle** or **Parallelogram.** Multiply the length by the breadth.

2. **Triangle.** Multiply the base by the perpendicular height, and take half the product.

Or: From half the sum of the three sides subtract each side separately, multiply the half sum and the three remainders together; the square root of the product will be the area.

3. **Trapezoid.** Multiply half the sum of the parallel sides into the perpendicular distance between them.

4. **Quadrilateral.** Divide the quadrilateral into two triangles; the sum of the areas of the triangles is the area.

5. **Irregular Polygon.** Divide the polygon into triangles, and trapezoids by drawing diagonals; find the areas of these as above shown for the area.

6. **Regular Polygon.** Multiply the length of a side by the perpendicular height to the centre and by the number of sides, and half the product will be the area.

7. **Circle.** Multiply the square of the radius by 3·14159.

Or: Multiply the square of the diameter by ·7854.

8. **Circular Ring.** Find the area of each circle, and

subtract the area of the inner circle from the area of the outer circle.

Or: Multiply the sum of the radii by their difference, and the product by 3·14159.

9. **Sector of a Circle.** As 360 is to the number of degrees in the angle of the sector, so is the area of the circle to the area of the sector.

Or: Multiply half the length of the arc of the sector by the radius.

10. **Segment of a Circle.** Find the area of the sector which has the same arc, and subtract the area of the triangle formed by the radial sides of the sector and the chord of the arc; the difference, or the sum of these areas, will be the area of the segment, according as it is less, or greater than a semicircle.

11. **Cycloid.** Multiply the area of the generating circle by three.

12. **Parabola.** Multiply the base by the height; two-thirds of the product is the area.

13. **Ellipse.** Multiply the product of the two axes by ·7854.

NOTE.—The area of an ellipse is equal to the area of a circle, of which the diameter is a mean proportional between the two axes.

II.—VOLUMES.

14. **Parallelopiped, Prism, or Cylinder.** Multiply together the length, the breadth, and the height, and the product will be the volume.

Or: Multiply the area of the base by the height, and the product will be the volume.

15. **Pyramid or Cone.** Multiply the area of the base by the height, and one-third of the product will be the volume.

16. **Wedge.** To twice the length of the base add the length of the edge; multiply the sum by the breadth of the base, and by the height. One-sixth of the result will be the volume.

17. **Sphere.** Multiply the cube of the diameter by ·5236.

18. **Spherical Shell.** Subtract the cube of the inner diameter from the cube of the outer diameter, and multiply the result by ·5236.

19. **Zone of Sphere.** To three times the sum of the squares of the radii of the ends add the square of the height; multiply the sum by the height and by ·5236.

20. **Segment of Sphere.** To three times the square of the radius of the base add the square of the height; multiply the sum by the height, and the product by ·5236.

TABLE VIII.

WEIGHT OF TWELVE INCHES SQUARE OF VARIOUS METALS.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Gun Metal.	Brass.	Copper.	Tin.	Zinc.	Lead.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{16}$	2·50	2·34	2·56	2·75	2·69	2·87	2·37	2·25	3·68
$\frac{1}{8}$	5·	4·69	5·12	5·5	5·38	5·75	4·75	4·5	7·37
$\frac{3}{16}$	7·50	7·03	7·68	8·25	8·07	8·62	7·12	6·75	11·05
$\frac{1}{4}$	10·	9·38	10·25	11·	10·75	11·5	9·5	9·	14·75
$\frac{5}{16}$	12·5	11·72	12·81	13·75	13·45	14·37	11·87	11·25	18·42
$\frac{3}{8}$	15·	14·06	15·36	16·50	16·14	17·24	14·24	13·50	22·10
$\frac{7}{16}$	17·5	16·41	17·93	19·25	18·82	20·12	16·17	15·75	25·80
$\frac{1}{2}$	20·	18·75	20·5	22·	21·5	23·	19·	18·	29·5
$\frac{9}{16}$	22·5	21·10	23·06	24·75	24·20	25·87	21·37	20·25	33·17
$\frac{5}{8}$	25·	23·44	25·62	27·50	26·90	28·74	23·74	22·50	36·84
$\frac{11}{16}$	27·5	25·79	28·18	30·25	29·58	31·62	26·12	24·75	40·54
$\frac{3}{4}$	30·	28·12	30·72	33·00	32·28	34·48	28·48	27·	44·20
$\frac{13}{16}$	32·5	30·48	33·28	35·75	34·95	37·37	30·87	29·25	47·92
$\frac{7}{8}$	35·	32·82	35·86	38·50	37·64	40·24	32·34	31·5	51·6
$\frac{15}{16}$	37·5	35·16	38·43	41·25	40·32	43·12	35·61	33·75	55·36
1	40·	37·5	41·	44·	43·	46·	38·	36·	59·

TABLE IX.

WEIGHT OF CAST IRON CYLINDERS ONE FOOT LONG.

External Diameter.	Thickness in Inches.						
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	6·75	9·65	12·3	14·6	16·6	18·3	19·6
3½	7·98	11·5	14·7	17·6	20·3	22·6	24·5
4	9·20	13·3	17·2	20·7	24·0	26·9	29·5
4½	10·4	15·2	19·6	23·8	27·7	31·1	34·4
5	11·7	17·0	22·1	26·9	31·5	35·4	39·3
5½	12·9	18·9	24·5	29·9	35·2	39·7	44·2
6	14·1	20·7	27·0	33·0	38·9	44·0	49·1
6½	15·3	22·5	29·5	36·1	42·6	48·3	54·0
7	16·6	24·4	31·9	39·1	46·4	52·6	58·9
7½	17·8	26·2	34·4	42·2	50·1	56·9	63·8
8	19·0	28·1	36·8	45·3	53·8	61·2	68·7
8½	20·3	29·9	39·3	48·3	57·5	65·5	73·6
9	21·5	31·8	41·7	51·4	61·3	69·8	78·5
9½	22·7	33·6	44·2	54·5	65·0	74·1	83·5
10	23·9	35·4	46·6	57·5	68·7	78·4	88·4
11	26·4	39·1	51·5	63·7	76·0	87·0	98·2
12	28·8	42·8	56·5	69·8	83·4	95·6	108·0
13	31·3	46·5	61·4	75·9	90·7	104·2	117·8
14	33·8	50·2	66·3	82·1	98·0	112·8	127·6
15	36·2	53·8	71·2	88·2	105·4	121·3	137·4
16	38·7	57·5	76·1	94·3	112·7	129·9	147·3
17	41·1	61·2	81·0	100·5	120·0	138·5	157·1
18	43·6	64·9	85·9	106·6	127·4	147·1	166·9
19	46·0	68·6	90·8	112·8	134·7	155·7	176·7
20	48·5	72·3	95·7	118·9	142·0	164·3	186·5
21	50·9	75·9	100·6	125·0	149·4	172·9	196·4
22	53·4	79·6	105·5	131·2	156·7	181·5	206·2
23	55·8	83·3	110·5	137·3	164·0	190·1	215·0
24	58·3	87·0	115·4	143·4	171·4	198·7	225·8

TABLE X.—*c[illegible]d.*

.....	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.
25	60·8	90·7	120·3	149·6	178·7	207·2	235·6
26	63·2	94·3	125·2	155·7	186·1	215·8	245·4
27	65·7	98·0	130·1	161·8	193·4	224·4	255·3
28	68·1	101·7	135·0	168·0	200·7	233·0	265·1
29	70·6	105·4	139·9	174·1	208·1	241·6	274·9
30	73·0	109·1	144·8	180·2	215·4	250·2	284·7
31	75·5	112·8	149·7	186·4	222·7	258·8	294·5
32	77·9	116·4	154·6	192·5	230·1	267·4	304·3
33	80·4	120·1	159·5	198·7	237·5	276·0	314·2
34	82·8	123·8	164·5	204·8	244·8	284·6	324·0
35	85·3	127·5	169·4	210·9	252·2	293·1	333·8
36	87·8	131·2	174·3	217·1	259·5	301·7	343·6
38	92·7	138·5	184·1	229·3	274·3	318·9	363·2
40	97·6	145·9	193·9	241·6	289·0	336·1	382·9
42	02·5	153·3	203·7	253·9	303·7	353·3	02·5
45	09·8	164·3	218·5	272·3	325·8	379·1	32·0
48	17·2	175·4	233·2	290·7	347·9	04·8	61·4
51	24·6	186·4	247·9	309·1	370·0	30·6	90·9
54	31·9	197·5	262·6	327·5	392·1	56·4	20·3
57	39·3	208·5	277·4	345·9	414·2	82·1	49·8
[illegible]	46·6	219·6	292·1	364·3	436·3	07·9	79·3

TABLE X.

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Cast Iron=1		Bar Iron=1		Steel=1	
Bar Iron	=1·0484	Cast iron	= ·9538	Cast iron	= ·929
Steel	=1·0766	Steel	=1·0269	Bar iron	= ·97378
Brass	=1·153	Brass	=1·1	Brass	=1·07
Copper	=1·2137	Copper	=1·15163	Copper	=1·1236
Gun metal	=1·208	Gun metal	=1·15094	Gun metal	=1·12132
Lead	=1·5645	Lead	=1·5	Lead	=1·4532

Brass=1		Copper=1		Gun Metal=1	
Cast iron	= ·867	Cast iron	= ·83	Cast iron	
Bar iron	= ·909	Bar iron	= ·8666	Bar iron	= ·86874
Steel	·9336	Steel	= ·89	Steel	= ·891735
Copper	=1·05	Brass	= ·95	Brass	= ·95583
Gun metal	=1·046	Gun metal	= ·9994	Copper	=1·00045
Lead	=1·357	Lead	=1·293	Lead	=1·29246

Lead=1		Yellow Pine=1	
Cast iron	=·64	Cast iron	=16·0
Bar iron	=·67	Steel	=17·0
Steel	=·688	Brass	=18·8
Brass	=·737	Gun metal	=19·0
Copper	=·774	Copper	=19·3
Gun metal	=·7736	Lead	=24·0

TABLE XI.

WEIGHT OF CAST IRON BALLS.

Diameter in inches	Weight in lbs.	Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
$2\frac{1}{4}$	1·57	$6\frac{1}{4}$	33·62	$10\frac{1}{4}$	148·28
$2\frac{1}{2}$	2·15	$6\frac{1}{2}$	37·80	$10\frac{1}{2}$	159·40
$2\frac{3}{4}$	2·86	$6\frac{3}{4}$	42·35	$10\frac{3}{4}$	171·05
3	3·72	7	47·21	11	183·29
$3\frac{1}{4}$	4·71	$7\frac{1}{4}$	52·47	$11\frac{1}{4}$	196·10
$3\frac{1}{2}$	5·80	$7\frac{1}{2}$	58·06	$11\frac{1}{2}$	209·43
$3\frac{3}{4}$	7·26	$7\frac{3}{4}$	64·09	$11\frac{3}{4}$	223·40
4	8·81	8	70·49	12	237·94
$4\frac{1}{4}$	10·57	$8\frac{1}{4}$	77·32	$12\frac{1}{4}$	253·13
$4\frac{1}{2}$	12·55	$8\frac{1}{2}$	84·56	$12\frac{1}{2}$	268·97
$4\frac{3}{4}$	14·76	$8\frac{3}{4}$	92·24	$12\frac{3}{4}$	285·37
5	17·12	9	100·39	13	302·41
$5\frac{1}{4}$	19·93	$9\frac{1}{4}$	108·98	$13\frac{1}{4}$	320·80
$5\frac{1}{2}$	22·91	$9\frac{1}{2}$	118·06	$13\frac{1}{2}$	338·81
$5\frac{3}{4}$	26·18	$9\frac{3}{4}$	127·63	$13\frac{3}{4}$	357·93

TABLE XII.

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch the integer or whole number.

·96875	qua	$\frac{7}{8}$ & $\frac{3}{32}$	·625	are equal to	$\frac{5}{8}$	·28125	are equal to	$\frac{1}{4}$ & $\frac{3}{32}$
·9375		$\frac{7}{8}$ & $\frac{1}{16}$	·59375		$\frac{1}{2}$ & $\frac{3}{32}$	·25		$\frac{1}{4}$
·90625		$\frac{7}{8}$ & $\frac{1}{32}$	·5625		$\frac{1}{2}$ & $\frac{1}{16}$	·21875		$\frac{1}{8}$ & $\frac{3}{32}$
·875		$\frac{7}{8}$	·53125		$\frac{1}{2}$ & $\frac{1}{32}$	·1875		$\frac{1}{8}$ & $\frac{1}{16}$
·84375		$\frac{3}{4}$ & $\frac{3}{32}$	·5		$\frac{1}{2}$	·15625		$\frac{1}{8}$ & $\frac{1}{32}$
·8125		$\frac{3}{4}$ & $\frac{1}{16}$	·46875		$\frac{3}{8}$ & $\frac{3}{32}$	·125		$\frac{1}{8}$
·78125		$\frac{3}{4}$ & $\frac{1}{32}$	·4375		$\frac{3}{8}$ & $\frac{1}{16}$	·09375		$\frac{3}{32}$
·75		$\frac{3}{4}$	·40625		$\frac{3}{8}$ & $\frac{1}{32}$	·0625		$\frac{1}{16}$
·71875		$\frac{5}{8}$ & $\frac{3}{32}$	·375		$\frac{3}{8}$	·03125		$\frac{1}{32}$
·6875		$\frac{5}{8}$ & $\frac{1}{16}$	·34375		$\frac{1}{4}$ & $\frac{3}{32}$			
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